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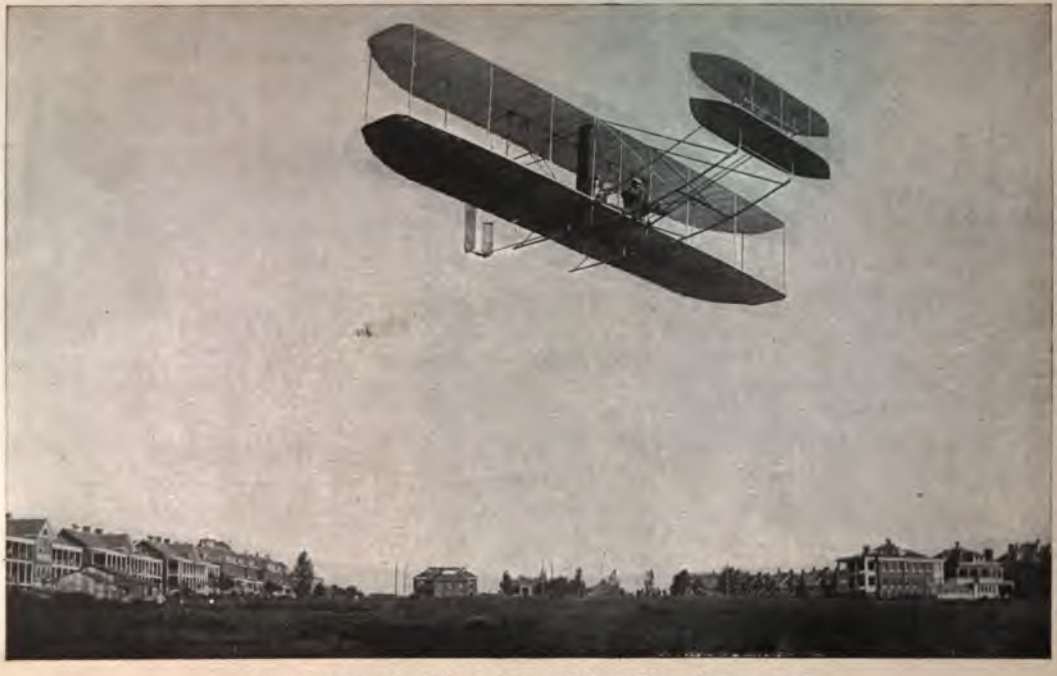

Orville Wright's Flight at Fort Myer, Va., Sept. 9, 1908.

# NEW CONQUEST OF THE AIR

OR

## THE ADVENT OF AËRIAL NAVIGATION

BY

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# PREFACE

THE final conquest of the air by man finds no popular and, at the same time, scientific account, in English, of its accomplishment. While the rapid progress which is daily being made in aërial navigation necessarily renders any permanent record of the latest achievements impossible, yet the epoch when mechanical flight was demonstrated to the world seems opportune to chronicle the past and present status of the art and to forecast its future.

The physical conditions which prevail in the ocean of air being even more important to the aëronaut than the conditions on bodies of water are to the sailor, a knowledge of the former is of vital interest. Accordingly, it appeared appropriate that, at the outset, there should be given a description of the ocean above our heads, including the surveys and soundings which have been executed by the author during the past twenty years at his own observatory. These and similar meteorologi-

cal researches, also undertaken elsewhere in the interest of pure science, now become of practical value to the aërial traveler.

The general facts concerning aërial navigation have been derived at first hand from authorities in Europe and America, the data are quoted from reliable sources, and the illustrations are reproduced from materials collected by the author or from the best pictures that have been published in foreign periodicals. Mr. Octave Chanute, of Chicago, whose knowledge of aëronautics is unsurpassed, has kindly consented to read the proof-sheets.

BLUE HILL METEOROLOGICAL OBSERVATORY,
MILTON, MASS.
*April,* 1909.

## PREFACE TO SECOND EDITION

THE enormous progress which has been made in the science of mechanical flight since the publication of the first edition has necessitated a complete revision of the text. I take this opportunity of cordially thanking all those who have assisted me in the work of revision, and especially Mr. Clarence D. Hanscom, whose aid has been invaluable. It is hoped that the book may prove its worth by giving to the reader some idea of the achievements of the pioneers and of their steady progress towards the conquest of the most unstable of elements, as well as of the status of aërial navigation today and its probable position in the future.

ALEXANDER KLEMIN.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
CAMBRIDGE, MASS.
*September,* 1917.

# CONTENTS


| CHAPTER | | PAGE |
|---|---|---|
| I | The Ocean of Air | 1 |
| II | The History of Aërostation | 36 |
| III | The Dirigible Balloon | 68 |
| IV | The Flying Machine | 115 |
| V | The History of Aviation | 138 |
| VI | The Future of Aërial Navigation | 181 |
| | Georges Guynemer | 192 |

# LIST OF ILLUSTRATIONS

Orville Wright's Flight at Fort Myer, Va., Sept. 9, 1908 . . . . . *Frontispiece*

PAGE

Fig. 1.—Comparative Altitudes . . . . . 5

Fig. 2.—Annual Isotherms above St. Louis . . 9

Fig. 3.—Diurnal Temperatures at Different Heights . . . . . 13

Fig. 4.—Vertical Gradients above Blue Hill . . 15

Fig. 5.—Sea of Clouds Seen from a Balloon . . . . . facing p. 18

Fig. 6.—Diurnal Wind-Velocities at Different Heights . . . . . 19

Fig. 7.—Courses of *Ballons-Sondes* from St. Louis . . . . . 26

Fig. 8.—Trade and Counter-Trade Winds . . . 32

Fig. 9.—Lana's Airship . . . . . 38

Fig. 10.—Besnier's Flying-Machine . . . . . 39

Fig. 11.—First Aërial Voyage . . . . facing p. 48

Fig. 12.—Second Aërial Voyage . . . facing p. 54

Fig. 13.—Jeffries and Blanchard Arriving in France . . . . . facing p. 58

Fig. 14.—Highest Ascent of Glaisher and Coxwell . . . . . facing p. 59

Fig. 15.—Ascent of *Preussen* . . . . facing p. 61

Fig. 16.—*Ballon-Sonde* Rising from St. Louis . . . . . facing p. 60

# ILLUSTRATIONS

PAGE

Fig. 17.—Captive Balloon at Battle of Fleurus . . . . . facing p. 61
Fig. 18.—An American Kite-Balloon . . facing p. 62
Fig. 19.—The *France* over Paris . . . facing p. 74
Fig. 20.—Military Dirigible the *République* facing p. 82
Fig. 21.—Dirigible the *Clément-Bayard* . facing p. 86
Fig. 22.—*Zeppelin IV* on Lake Constance . facing p. 90
Fig. 23.—Voyage of *Zeppelin IV* . . . . . 93
Fig. 24.—The Passenger Zeppelin *Schwaben* . . . . . facing p. 86
Fig. 25.—Astra-Torrès Coast Patrol Airship . . . . . facing p. 102
Fig. 26.—A British Submarine Scout Airship . . . . . facing p. 108
Fig. 27.—An American "Blimp" . . . facing p. 108
Fig. 28.—French Anti-Aircraft Gun . . facing p. 112
Fig. 29.—A French "Parasol" Monoplane facing p. 128
Fig. 30.—A 100 H. P. Gnome Rotary Engine . . . . . facing p. 128
Fig. 31.—Langley *Aërodrome* in Flight . facing p. 140
Fig. 32.—Langley's *Aërodrome* as flown in 1914 . . . . . facing p. 140
Fig. 33.—Lilienthal Glider Descending . facing p. 144
Fig. 34.—Wright Glider Descending . . facing p. 144
Fig. 35.—The First Wright Airplane . . facing p. 148
Fig. 36.—*June Bug* in Flight . . . . facing p. 148
Fig. 37.—A Typical Pusher Biplane—The M. Farman of 1914 . . . . . facing p. 160
Fig. 38.—A Dunne-Type Airplane . . . facing p. 160
Fig. 39.—Macchi Flying Boat . . . . facing p. 164

# CHAPTER I

## THE OCEAN OF AIR

BEFORE discussing the methods of aërial navigation, it will be advantageous to consider the medium in which this must take place. The atmospheric ocean, at the bottom of which we live and move and have our being, presents analogies to the aqueous ocean upon which it rests. The lower portion of the former and the upper surface of the latter we know best, and it was to aid marine navigation that contiguous currents in both oceans were determined. By means of government expeditions, likewise, the depths, thermometric and hydrometric conditions of the oceans traversed by ships have been ascertained, but the ocean above our heads has been explored almost entirely in the interest of pure science and without the expectation of practical benefits. Apart from observations on mountain-tops, which give results that do not represent the conditions of the free air, the study of the high atmosphere has been

undertaken systematically only within the past fifteen years and the fact that the atmosphere has no boundaries and can be pre-empted by no nation makes its exploration a truly international undertaking. This is being done through monthly kite and balloon ascensions under the auspices of the International Commission for Scientific Aëronautics, and the field of survey has lately been extended to Asia and Africa and the tropical and arctic oceans. The first meteorological records with kites were obtained at Blue Hill Observatory, near Boston, in 1894; the method was used at sea by the author in 1901, and three years later the temperature 10 miles above the American continent was ascertained by means of sounding balloons sent up under his direction. At the present time the aëro-physical observatory of the United States Weather Bureau is making daily kite flights and the extraordinary height of more than four miles has been attained. From all these sources many data are being accumulated which, while primarily intended to increase our knowledge of the physics of the globe, will also prove as useful to the aërial voyager as are the ocean pilot charts to the mariner.

Let us now compare, in a general way, the aërial and aqueous oceans. The former completely envelops the globe and rests lightly upon the other ocean that covers the greater portion of the crust with its tremendous weight. The atmosphere extends with diminishing density to an indefinite height, while the lesser depths of the sea are absolutely defined. Both oceans receive their heat from the sun, chiefly by radiation and absorption at their junction with each other, and therefore both become colder as we penetrate into them, so that near their superior and inferior portions, respectively, the lowest temperatures occur. Water is almost incompressible, and expands much less by heat than does the elastic air, consequently the currents in the latter are far more active and the cold in its higher regions results chiefly from cooling by expansion of the rising currents, whereas the cold at the bottom of the sea is the result of the descent of the denser water flowing from the poles. The rate of decrease of temperature with increasing depth in the water is faster than with increasing height in the air and in both is most rapid at the equator. There is a semi-diurnal tide in the lower air like that on the surface of

the sea, but the irregular changes of pressure amounting sometimes to one-fifteenth of the whole atmospheric pressure, produce the violent circulation in storms.

Such, then, are some of the similarities and differences between the superior and inferior oceans, on the border-line of which man has hitherto been content to live. While the seas have been completely mastered by man, at least superficially, the atmosphere offers to his ingenuity a medium that is equally navigable through a great thickness, and which dominates seas and mountains and so unites the nations. Obstacles to its use are the small supporting power which it affords and the violent commotions to which it is subject. Moreover, while a ship, by utilizing the resistance of the relatively stationary water on its side and rudder can deviate from the wind, a balloon resembles a submarine boat, and if it possesses no motive power must drift with the current in which it is wholly immersed. However, as will be shown later, by taking advantage of a superposed or underlying air current blowing in an opposed direction, it may be possible for such an aërial craft to return to its starting point.

FIG. 1.— Comparative Altitudes.

An idea of how far the ocean of air has been explored is given in Fig. 1, which represents a vertical section of the atmosphere with the barometric pressures at the left which correspond to the successive heights marked on the right. The right-hand half of the diagram includes the eastern hemisphere and the highest mountains on the globe with the line of permanent snow and the greatest height to which man has climbed. The observatories on the Misti, in Peru, and on Mont Blanc, that had self-recording instruments, as well as the highest permanently inhabited place, are indicated. As regards the free air we see the relative levels reached by a kite and by man in a balloon and, at the top of the diagram, the height reached by *ballons-sondes,* which carry only self-recording instruments. The extreme height reached by such a balloon is 18 miles, which is more than twice as high as a human being can hope to attain, for the atmospheric pressure there is but a fraction of an inch of mercury, instead of 30 inches, which is the average density of the air that we breathe at sea-level. It may be perceived from the diagram that the pressure is reduced, generally speaking, about one-half for each three and a

half miles of ascent, although the intervals diminish progressively upward. This rapid rarefaction makes it practically certain that the navigable portion of the air lies below seven miles, since here the atmospheric pressure becomes only a quarter of the normal. This lower portion of the atmosphere, which contains three-quarters of the whole mass, is unfortunately the region of storms and of the clouds which accompany them, for only occasionally are the cirrus, or ice-clouds, seen as high as nine miles. The winds which blow around our centers of low barometric pressure are replaced, above two or three miles, by the nearly constant, but rapid planetary circulation of the atmosphere, which, in temperate latitudes, is from west to east.

As was remarked, a great deal of information about the free air has been gathered by sending into the air instruments attached to kites and *ballons-sondes,* or sounding balloons. The latter are small balloons, now commonly made of sheet rubber, which carry barometers and thermometers especially designed to record very low pressures and temperatures, graphically and continuously. After the balloons reach their highest altitude they fall to the

ground, where they are generally found and returned to the sender, and from the automatic records of their instruments the heights reached from moment to moment can be calculated, together with the temperature prevailing at these heights. Instruments lifted by kites show in more detail the conditions within two or three miles of the ground, and have the advantage of furnishing the data with greater certainty and nearly vertically over the station on the ground. The humidity can thus be measured and also the velocity of the wind, because the kite may remain stationary in any current at the will of the operator. Clouds, which float at different heights in the atmosphere, also afford a method of determining the direction and velocity of the air-currents. If the average heights of the different classes of clouds have been computed from angular measurements on a base-line, measurements of the apparent motion of these clouds will enable their true velocity, as well as their direction of motion, to be obtained at any time with sufficient accuracy. All these methods have been employed by the staff of the Blue Hill Observatory, obviating the necessity of ascending into the air themselves, and the results which will

be given typify the general conditions prevailing over the United States. In order to obtain a continuous series of observations at a fixed height above sea-level, it is still necessary to make them on mountains, but, since these

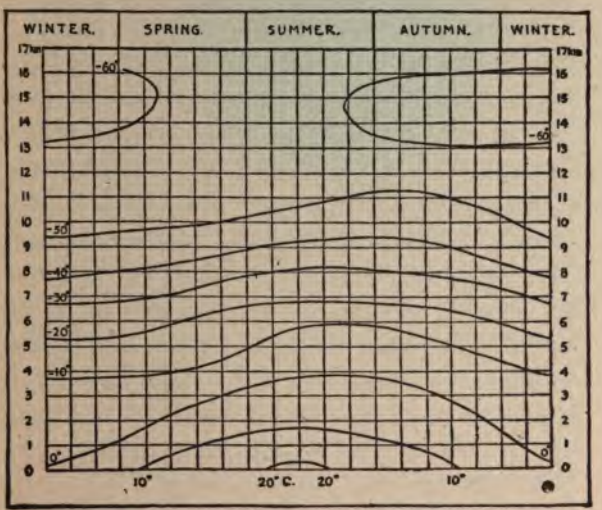


FIG. 2.—Annual Isotherms above St. Louis.

form a part of the earth's crust, such observations, even when made on an isolated peak, do not represent the conditions at an equal height in the free air, because the mass of the mountain influences the temperature and moisture

of the surrounding air and modifies the air currents which come in contact with it.

The temperature is of considerable importance to the aëronaut. It was said that, as we rise in the atmosphere, the temperature decreases, and, as a matter of fact, this occurs so rapidly that in an ascent of a few hundred feet the change in temperature corresponds to a displacement in latitude on the earth's surface of several hundred miles. Fig. 2 shows the height of the isotherms, or lines of equal temperature, at each season, obtained from the records of 62 ascensions of *ballons-sondes* at St. Louis. In this and the following diagrams the heights are expressed in kilometers, 16 kilometers being equivalent to 10 miles. The temperatures are given in Centigrade degrees, so that 0° C. is equivalent to 32° F., 20° C. to 68° F., and minus 60° C. to 76° F. below zero. The diagram shows that the line of 0° C. nearly touches the ground at St. Louis in the winter, but in midsummer rises 3,800 meters above it, the surface temperature being more than 20° C. It will be noticed that the curves of equal temperature preserve approximately the same form and distance apart, though they are somewhat more crowded above six kilometers, show-

ing that the most rapid decrease of temperature is here. In fact, the rate of decrease nearly equals the adiabatic change for dry air, namely, 1° C. per 100 meters, or 1° F. per 183 feet, which is the cooling produced by the expansion of the air as it ascends, without the passage of heat to or from the air. Above 13 kilometers, however, the decrease of temperature is generally transformed into an increase of temperature with increasing height, though the height of this plane of inversion varies with the season. The cause and thickness of the warm stratum are unknown, but it was found to persist in Europe at 29 kilometers, or 18 miles, and it appears completely to surround the globe, being highest over the equator, and lowest in the arctic regions. However, it is only relatively warm, as the temperature is still some 70° F. below zero. The observations in the United States prove that in this warm stratum, between about 13 and at least 17 kilometers, there is nearly always a rise of temperature. For instance, on October 8, 1907, the temperature rose 9° C., between 14,500 and 16,000 meters. Taking another example, on November 6, 1907, the minimum temperature of —52° C. was found at 9,700 meters, and

increased nearly 2° C. within the next 300 meters, whereas on November 8, the minimum temperature of — 63° C. occurred at 14,250 meters and rose 3° in the succeeding 1,130 meters, showing a change in level of the warm stratum of 4,550 meters within two days.

In the preceding diagram the seasonal effect of temperature is evident up to 10 kilometers, a height which has been attained by aëronauts, although the period of greatest warmth is retarded so that it here occurs in the autumn, as evinced by the maximum height of the isotherm of — 50° C. at that season. While the upper isotherm of — 60° C. represents the lowest average temperature at any height, yet an extreme temperature of — 79° C., or 110° F. below zero, was recorded in January, 1905, at a height of 14,800 meters, or about nine miles, this being one of the lowest natural temperatures ever observed in the air or on the earth, and even in the following July,— 59° C., or 75° F. below zero, was registered at a slightly lower altitude. While the heights at which these temperatures were recorded probably can never be reached by human beings, yet, even at the altitudes to which aëronauts do ascend, it is intensely cold throughout the year, and this,

combined with the rarefaction of the air, acts as a barrier to the attainment of greater heights.

For many years the conditions which pre-

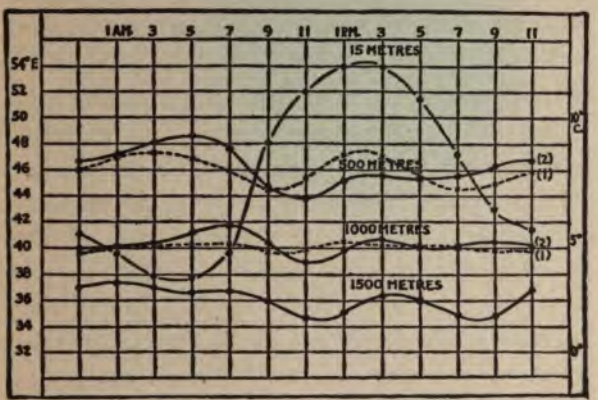


FIG. 3.—Diurnal Temperatures at Different Heights.

vail in the lower mile or two have been observed with kites at Blue Hill, and like the balloon observations, the results of their study by Mr. Clayton, meteorologist at the Observatory, are published in its *Annals,* and only some of them can be briefly stated here.

While it was seen that the seasonal and non-periodic changes of temperature are felt even at great heights, we shall find that this is not

true for the average hourly changes which are exhibited in Fig. 3. Here the curves for three levels are plotted for every two hours with their values in Fahrenheit degrees on the left and in Centigrade degrees on the right. The curve for 15 meters elevation is for a station on the ground and shows the well-known diurnal range of temperature with the maximum in the early afternoon and the minimum in the early morning. The three other curves were obtained in the free air with the kite at 500, 1,000 and 1,500 meters (almost a mile), respectively; the dotted lines for the first two representing the results of a different method of reducing the data. They all show a diminished range of temperature from that at the ground, and in the curves at the highest levels the phases of the ground-curve are almost reversed, so that it is warmest at night and coldest about noon. Curves plotted for the relative humidity at these same heights show them to be nearly the inverse of the temperature curves, that is, the lower mile of air, excepting the surface-stratum, is, relatively, warm and dry at night and cold and damp in the daytime.

The average vertical gradients of these two

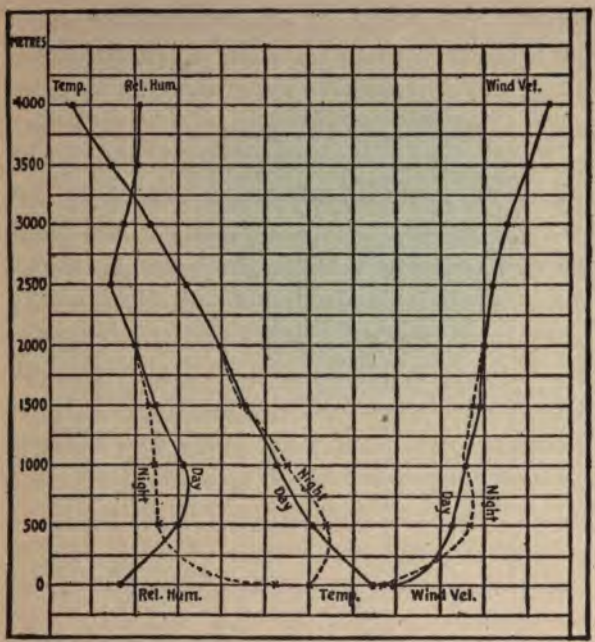


FIG. 4.—Vertical Gradients above Blue Hill.

elements and also of wind velocity, up to a height of 4,000 meters, or two and a half miles, are plotted in Fig. 4. Here the lines inclining upwards to the right indicate increasing values, and lines leaning to the left decreasing values, the dotted lines showing the nocturnal conditions. The temperature in the daytime de-

creases with height in the manner described, but at night is seen to increase up to the vicinity of 500 meters above the ground, on account of the nocturnal cooling of the soil by radiation and the consequent chilling of the contiguous air. The relative humidity increases in the daytime up to about 1,000 meters, and then falls to a minimum above the lower clouds at the height of a mile and a half. At night, however, it is already dry a quarter of a mile above the ground, because of the absence of ascending currents of air. It should be remembered that all these are average conditions, for strata are found at every height which differ greatly in temperature and humidity from the adjacent air, and are accompanied by abrupt changes in the direction and velocity of the wind.

Clouds constitute an obstacle to aërial navigation. If the aëronaut is enveloped in a cloud, or is between two strata which obscure both the earth and the sun or stars, he cannot tell where he is or whither he is going, and, moreover, moisture and, in greater degree, rain or snow overload his airship or disturb its balance. A balloon may be destroyed in the air by lightning and the up-rush of wind in the

cumulo-nimbus, or thunder-shower clouds would jeopardize any airship caught in its embrace. The heights of the typical clouds, namely, nimbus, cumulus, alto-cumulus, cirro-cumulus, cumulo-nimbus and cirrus, which are much the same all over the world, were shown in Fig. 1. They tend to arrange themselves in distinct levels, with a maximum frequency between three-quarters of a mile and a mile and a quarter, and in other zones of frequency at regular intervals up to about six miles. We may place at eight miles the upper limit of the cirriform clouds, appearing to us on the earth as filaments, or as a thin veil through which the sun is faintly visible, but which are recognized as floating ice-crystals by aëronauts who have traversed them at a height of five or six miles. Rain or snow may fall from alto-nimbus, a uniform cloud-sheet more than a mile above the ground, but commonly comes from a ragged sheet of nimbus about half a mile high. In summer rain or hail also falls from cumulo-nimbus, whose towering top often extends into the cirrus region, whereas the thickness of the ordinary raincloud does not exceed two miles, and may be traversed usually by a balloon. On emerging from the darkness of the

cloud into the bright sunshine which illumines the white cloud-billows, we have the scene represented in Fig. 5, which was photographed by the author, near London, at a height of 6,000 feet. The shadow of the balloon, surrounded by an aureole, is seen upon the cloud in the middle of the foreground. Since the average height of the different classes of clouds is known, the apparent motion of a particular cloud when observed at the ground gives to the aëronaut, wishing to start on a voyage, quite accurate information about the direction and speed of the air currents prevailing at that height, and in this way clouds serve as a wind gauge for the upper air.

Of all the meteorological elements the wind is the one with which aëronauts and aviators are most concerned. The relative change of velocity with height is indicated in Fig. 4, in which the rapid increase for a short distance above the ground is conspicuous. At night the acceleration in velocity is even more marked, attaining its maximum at the height of one-third of a mile. Higher up, in the daytime, the velocity increases slowly, but at night decreases somewhat, except in winter, up to about 1,000 meters, or two-thirds of a mile.

FIG. 5.—Sea of Clouds Seen from a Balloon.

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Above this height there is a steady increase of wind velocity with height and the rate of increase is greater above 2,500 meters, or a mile and a half. Fig. 6 shows bi-hourly wind velocities at Boston, 60 meters; Blue Hill, 200 meters; and in the free air at 500 and 1,000

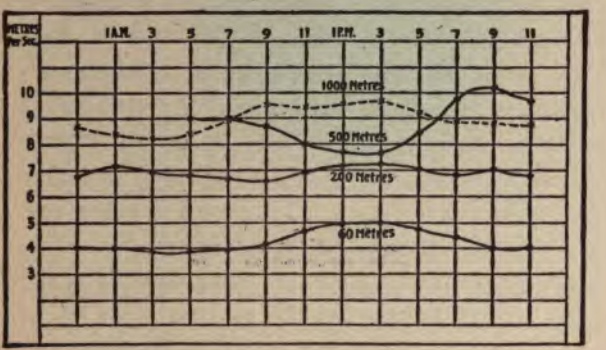


FIG. 6.—Diurnal Wind-Velocities at Different Heights.

meters. At Boston the wind velocity is distinctly greatest in the afternoon and least at night. On Blue Hill the diurnal change is small, but at 500 meters the period at the lower station is reversed, since the minimum velocity occurs in the afternoon and the maximum at night, and at 1,000 meters there are indications of a double maximum in the afternoon and at night and minima both in the

morning and afternoon. Therefore, between 300 and 500 meters the wind velocity during the night and early morning is considerably greater than for heights immediately above or below. On the scale of wind velocity, one meter per second corresponds to two and one-quarter miles per hour. With a high barometric pressure at the ground and in clear weather, the wind velocity increases slowly with altitude, but with a low barometer and in cloudy weather its velocity increases rapidly with altitude, especially near the strata of lower cloud.

Near the ground the wind is more gusty on account of the obstacles it encounters, which are analogous to reefs in the sea. At night, however, because there are no ascending currents, the wind is much steadier than in the daytime, making night the most favorable time for aërial navigation of all kinds. The uniformity of temperature, also, and the absence of intermittent sunlight through clouds, combine to make it possible at night to maintain a balloon at a constant level with small loss of gas. A suitable height in the daytime, unless a strong westerly wind is sought, lies above the cumulus clouds at the height of

about a mile, but at night it is not necessary to rise so high, and in summer a region of relatively little wind is found at a height of about three-quarters of a mile, where it is also warmer and drier than in the daytime or at the ground. Over the open sea the diurnal change in wind velocity is very small and the velocity increases more slowly with height than immediately over the land.

At greater heights the wind can best be determined from clouds, measured as already stated. By such measurements at Blue Hill the average increase in velocity between 2,000 and 12,000 meters (1¼ to 7½ miles) was found to be nearly one mile per hour for each 100 meters, or 330 feet, of ascent, being rather more than half a mile per hour in summer and a mile and a half in winter.

The actual velocities between the heights of half a mile and five miles were as follows:

| Height in Miles | | 0.5 | 1.2 | 2.5 | 4.7 | 5.0 |
|---|---|---|---|---|---|---|
| Velocity in Miles per Hour | Summer | 16 | 18 | 23 | 31 | 52 |
| | Winter | 19 | 32 | 47 | 108 | 119 |

In considering this rapid increase of velocity with height it must be remembered, also, if it is a question of the resistance of a body to the

air, that its pressure varies as the square of its velocity; so that doubling the velocity quadruples the pressure. Consequently, in augmenting a velocity from 19 miles to 119 miles per hour, which is the average speed of the currents in winter at the height of five miles, the pressure is increased from one pound to 43 pounds per square foot.[1] This is at sea-level, but at the altitude of five miles, owing to a diminution to three-eighths in the density of the air, the actual pressure upon a body having one square foot of flat surface exposed to a wind of 119 miles per hour would be reduced to 16 pounds. It is obvious, therefore, that the supporting power of the air is reduced in

[1] On Blue Hill an extreme velocity of 88 miles per hour during five minutes has been recorded in 20 years, which, according to the latest formula for converting velocity into pressure on a normal surface ($P = v^2 \times .003$) gives a pressure of 24 pounds per square foot. During the first four years of observation a self-recording pressure-plate was in operation, and on two occasions pressures of over 43 pounds on the square foot were registered, while the corresponding velocity during five minutes was only 85 miles per hour instead of 119 miles, as the pressure would indicate. This seems to show that the extreme pressures are of very short duration, perhaps lasting only a few seconds, and that the frequency and intensity of gusts is greatest at high velocities.

the same ratio, and since the resistance to propulsion through the air against head winds increases faster than their density diminishes, it follows that neither aëroplane nor dirigible balloon can be operated efficiently higher than is necessary to overcome the irregular conditions at the earth's surface. A balloon moving with the wind experiences but slight resistance, whereas a self-propelled apparatus which might be capable of traveling 10 miles per hour in still air would remain stationary, as regards the earth, when it encountered a contrary wind of 10 miles per hour, and yet there would be actually blowing against it the wind of 10 miles per hour, whose pressure was a third of a pound upon each square foot of surface normally exposed. If the machine could travel 20 miles per hour and the natural wind blew at half this rate against it, the machine would advance at the rate of 10 miles and would sustain a pressure of about one and a quarter pounds per square foot, the pressure increasing as the square of the velocity of the impinging air. Although at Blue Hill the average wind velocity is greatest in March and least in August, at a height of two miles each of these extremes occurs about two months earlier than they do

near the ground. Consequently, in this latitude, the months of June and July appear to be the most favorable season for self-propelled aërial craft. Assuming 18 miles per hour to be the highest average wind in which a dirigible balloon can be operated, such a balloon might ton, and 75 per cent. of the hours during the winter, up to a height of 600 feet above Boston, and 75 per cent. of the hours during the summer. Modern dirigibles have speeds so high that only severe storms can prevent flights.

It is generally assumed that the wind blows horizontally, and our ordinary anemometers measure only the horizontal component. A few years ago an instrument for recording the vertical component was in use at Zi-Ka-Wei, China, and on the Eiffel Tower in Paris, which showed the existence of both upward and downward currents. In 1891 such an instrument was exposed 30 feet above the tower of the Blue Hill Observatory, and observations were made during several months. Upward currents aggregating one thousand feet per day were recorded, due chiefly to the deflection of the horizontal wind on striking the hill, since the vertical wind was roughly proportional to the amount of horizontal wind, but

it was also related to the heating of the hill by the sun, being strongest in clear weather. Downward currents were seldom registered, proving that, though they undoubtedly exist, their velocity was too small to effect the fans of the anemometer. That these vertical currents may extend to considerable heights is shown by the production of cumulus clouds, under which kites have demonstrated the existence of strong ascensional currents. The wave-like appearance of the higher clouds is also evidence of undulatory movements which may extend downwards to the earth, and cause rhythmical oscillations of the barometer. We are not yet prepared to say to what extent these upward currents may be utilized to lift aëroplanes, and the theory that the soaring bird is always sustained by them has not yet been generally accepted.

The change in wind direction with increasing height, as indicated by the kites, is normally to the right when the velocity increases with altitude on account of the effect of the earth's rotation, but when the influence of the barometric gradient at the surface is no longer felt, a westerly current is found, no matter what may have been the direction of the wind

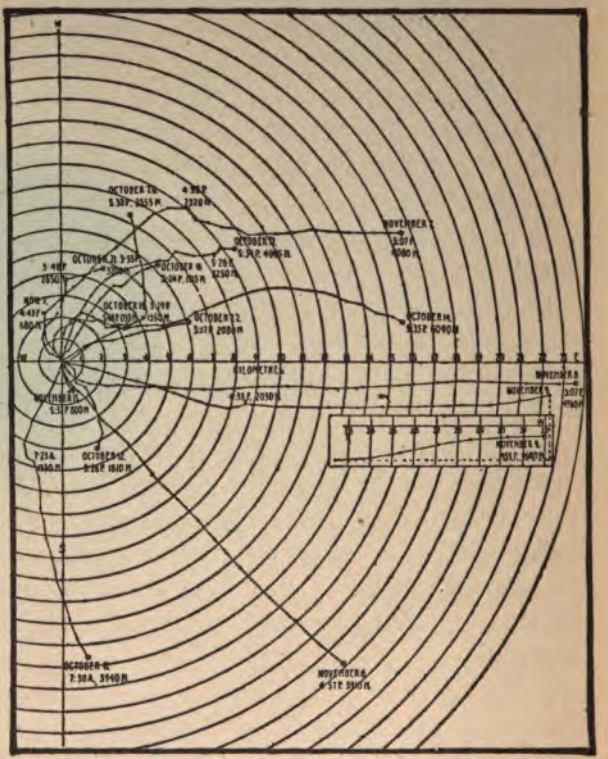

FIG. 7.—Courses of *Ballons-Sondes* from St. Louis.

at the earth's surface. Usually the change is quite abrupt, but sometimes the direction alters gradually with height until the currents become almost diametrically opposed to those below.

The same law for change of wind direction was shown by the *ballons-sondes* sent up from St. Louis, of which a good many were watched by a surveyor's transit until they disappeared at a height of about two and a half miles, and two were seen up to nearly four miles. The azimuth and angular elevation, when combined with the height recorded by the barometer which was carried by the balloon, permitted its change of direction at various levels, as well as the speed, to be calculated. The wind direction generally shifted to the right with increasing height for winds coming from the south and to the left for northerly winds, until, at the height of two miles, it blew slightly from the north of west with a velocity of about 19 miles per hour in May and 39 miles per hour in November. Since these data agree with those got from the kites at Blue Hill, it follows that the upper air currents over the interior of this continent do not differ from those above the Atlantic coast.

In Fig. 7 the directions and velocities of the balloons which were thus observed by Mr. Fergusson, of the Blue Hill staff, during October and November, 1907, are projected upon the ground. The concentric circles show the dis-

tance in kilometers from St. Louis, eight kilometers being equal to five miles, and the points on the courses of the balloons give the position at the time of observation with the transit, these observations being usually made every minute. The disappearance of each balloon is indicated by a circle at the end of the course when the time and altitude, in meters, are marked. The tendency of most balloons to come into a westerly current at their maximum height is evident from the diagram.

To obtain the directions and velocities of the currents at greater heights with *ballons-sondes,* the direction of the place of fall of each balloon with respect to the starting point, and the time required to traverse this distance as recorded by the instrument, can be used. For any ascension, however, this gives only the average direction and speed at a height which may be assumed to be one-half the maximum height recorded.

The data for 64 *ballons-sondes,* which were sent up by the author from St. Louis at different seasons, represent the average movement of the air above the middle of the American continent. In the table which follows, the data are separated into four levels, the lowest at the

bottom of the table including the balloons whose maximum heights were below 16,000 feet, the second, those in which the maximum heights were between 16,000 and 33,000 feet; the third, those between 33,000 and 49,000 feet, and the highest those above 49,000 feet. The heights are expressed in feet and the velocities in miles per hour, the directions being from whence the balloons came.

AVERAGE DRIFT OF BALLONS-SONDES FROM ST. LOUIS

| No. of Ascensions | Mean of Max. Altitudes | Mean Altitude | Mean Velocity | Mean Direction From |
|---|---|---|---|---|
| 13 | 52,000 | 26,000 | 43 | 12° N. of West |
| 24 | 40,000 | 20,000 | 52 | 17° N. of West |
| 16 | 25,000 | 12,000 | 40 | 14° N. of West |
| 11 | 12,000 | 6,000 | 29 | 12° N. of West |

It will be seen that the velocity of the air-currents increases up to the third level, and although the wind is already west at 6,000 feet, it turns slightly more to the north with increasing height. At the upper level the velocity decreases somewhat, and the direction turns back a little towards the west. The same peculiarities are noticeable in the air-movements for equal heights above Blue Hill, which

were obtained from the observations of clouds, therefore the phenomena appear to be general in this country.

The above are average results and the individual courses of the balloons differ widely, although all traveled to the eastward of St. Louis, excepting one or two, which did not rise above the surface wind. Large differences occur from day to day in both the direction and velocity of the air currents. The greatest velocity was shown by two balloons on successive days in November, which reached extreme heights of about seven miles, and traveled at an average speed of 100 miles an hour, one 280 miles east, the other 255 miles south-southeast. As this is the average velocity in the upper and lower air-strata, the velocity at the maximum altitude in both cases probably much exceeded 100 miles an hour, but such velocities are shown by the measurements of the drift of cirrus clouds at Blue Hill to be not unusual in winter over the United States. An instance of apparently very low velocity at a great height occurred on October 16, 1907, when a balloon which reached a height of nearly 10 miles traveled only 28 miles towards the southeast although it was

in the air three hours. In this case, which is illustrated in Fig. 7, we know from observations of the balloon that it was moving toward the northeast with a velocity of 30 miles an hour at the height of three-quarters of a mile. The direction was then seen to become easterly and its speed to diminish. At the end of 10 minutes the balloon had risen a mile and a quarter, and was four miles northeast of its starting point. For the next two hours and a half the balloon, at a high altitude, probably traveled in a general southeast direction at the rate of only 15 miles an hour, until it sank into the lower current, which again carried it a short distance northeast, and there it landed, 28 miles southeast of St. Louis.

While a balloon with no motive power must drift with the current in which it floats, it has been seen that by properly utilizing the different air-currents, its course can in some degree be controlled. For example, by rising a few miles into the air in temperate latitudes, a current from a general westerly quarter may always be found, no matter what was the direction of the surface wind. In the tropics, near the coast and at sea, above the permanent northeast and southeast trades the counter-

trades blow, respectively, from the southwest and northwest. As some doubt had been cast

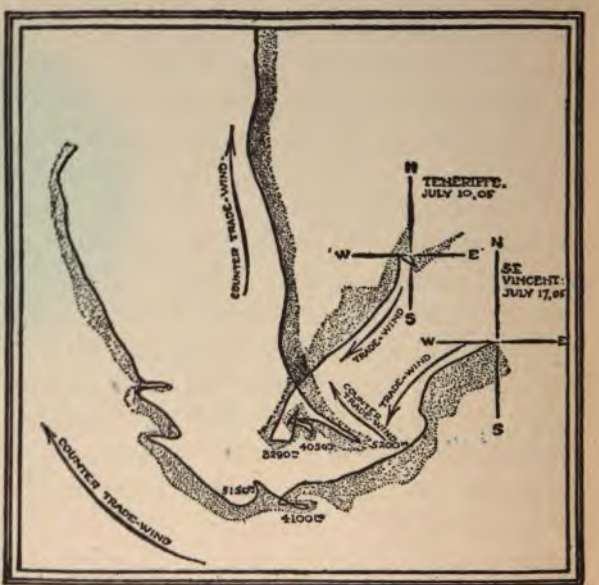


FIG. 8.—Trade and Counter-Trade Winds.

upon this phenomenon, an expedition was sent in 1905, jointly by Monsieur Teisserenc de Bort, the distinguished French meteorologist, and the author, to explore the atmosphere above the tropical Atlantic. Pilot balloons, dispatched from the islands of Teneriffe and

St. Vincent, were observed with theodolites at the ends of a base-line, and in this way the heights at which the balloons changed direction could be ascertained. Later the balloons were sent up from the yacht itself, which steamed after them, measurements being made of their angular elevation. The observations which are plotted in Fig. 8, prove conclusively the existence of the upper counter-trade. The courses of the balloons are represented as if projected upon the surface of the sea and show that the northeast trade-wind extended only to the height of 3,200 or 4,000 meters, and then gradually turned into a southerly current which, higher up, came from the southwest. The width of the dotted band represents approximately the varying velocity of the trade and counter-trade. Similar proofs of the northwest counter-trade, which is superposed on the southeast trade wind, south of the equator were obtained by the same expedition during the following year, but the above suffices to show that it would be possible for an aëronaut in an ordinary balloon to start from the African coast, or from some of the islands in the trade-wind region, and, after drifting towards the southwest, to rise a few miles into

the current, which would carry the balloon north and eventually northeast back to land. Nevertheless it does happen in certain atmospheric situations over the tropical north Atlantic that the winds from a general northwesterly direction prevail up to great heights without any evidence of the return-trade. Near the equator the winds are easterly up to the greatest heights which have been attained.

Along the Atlantic coast a sea-breeze blows inshore to a considerable distance on most summer afternoons, while above it the westerly wind prevails throughout the day, affording a means of sailing beyond the coast in the morning and returning with the lower wind in the afternoon. This method was employed by John Wise, the American aëronaut, more than fifty years ago. In the same way use may be made of other local winds such as those which blow up the valleys in the daytime and downwards at night.

Consequently we see that while an aërostat (which is the only aërial craft not self-propelled) cannot, like a ship, sail at an angle to the wind, except by the cumbersome device of towing a "deviator" through the water, yet in many cases, by the facility of ascending and

descending into other currents the aërostat may change its course and even return to the starting point. Dirigible balloons, like low-powered steam-vessels, may also profit by the prevailing winds, and, therefore, to ascertain the meteorological conditions which balloons and aëroplanes must encounter at different heights, places, and times, such knowledge as is outlined in this chapter will be eagerly sought.

Meteorology and aëronautics are mutually dependent upon one another. The exploration of the air will give better knowledge of the meteorology of the upper regions and will result, perhaps, in a more complete utilization of such natural forces as solar energy and wind. The sea, at present the great medium of international communication, is navigable only on its surface, except to a very limited extent, whereas the aëronaut can use a vast height of atmosphere. Oceans separate continents and mountains form natural boundaries between nations, but the atmosphere binds them all together in its embrace. Therefore, it appears certain that man will not rest until he has completely conquered the ocean of air by opening its domain to his activities.

## CHAPTER II

### THE HISTORY OF AËROSTATION

FROM the earliest times the vast realms which extend above us have tempted man's ambition and efforts. In the 4th century B. C., Archytas of Tarentum, a Pythagorean philosopher, invented a wooden dove which is said to have risen into the air and really flown. During the subsequent centuries there were obscure legends of men who attempted to fly, but not until the 13th century do we find anything so definite as the proposition of the English friar, Roger Bacon, "to fill a large, hollow globe of copper, wrought extremely thin, with ethereal air or liquid fire, and to launch it from some elevated point into the atmosphere where it will float like a vessel on the water." Bacon also wrote: "there may be made some flying instrument, so that a man sitting in the middle of the instrument and turning some mechanism may put in motion some artificial wings which may beat the air like a bird flying."

Leonardo da Vinci in the 16th century revived Bacon's last idea and his knowledge of human anatomy appears in the drawings which he left of a flying machine with jointed wings, which contracted on the upward stroke and expanded on the downward, and were intended to be driven by a man's legs and arms. The power needed would have been excessive.

Both these schemes were proposed in a somewhat more definite form at the end of the 17th century. In 1670 the Jesuit, Francis Lana, conceived that a vessel exhausted of air would weigh less than when full. He therefore proposed to construct four globes of copper each 20 feet in diameter and so thin that they would weigh less than an equal bulk of atmosphere when they were exhausted of air. To these globes a boat was attached, having also a mast and sail with which Lana supposed the aëronaut could direct his course. The apparatus is represented in Fig. 9, which is copied from *Prodromo all' Arte Maestra del P. Francesco Lana.* The principle of the hollow globes was correct and only the difficulty of providing a perfect vacuum and the weight of the globes thick enough to withstand the external pressure of the air prevented Lana from achieving

success. It may be regarded therefore as the prototype of the modern balloon.

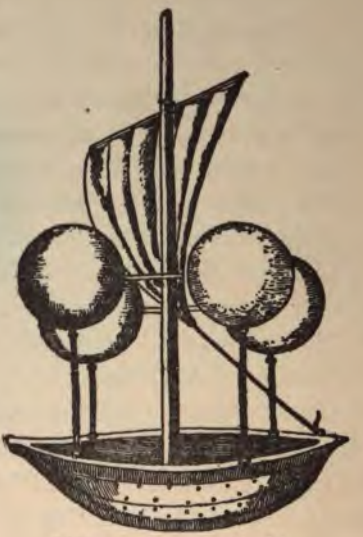

FIG. 9.—Lana's Airship.

The other device, which typifies the heavier-than-air flying machine, was constructed in 1678 by a French locksmith named Besnier, namely two pairs of wings, which opened and shut and oscillated about his shoulders by the action of feet and hands. This machine, as illustrated in the *Journal des Scavans,* is shown

in Fig. 10. Besnier did not pretend that he could rise from the ground or make a long flight, but he is said to have made some use of these wings to raise himself from one height to

FIG. 10.— Besnier's Flying-Machine.

another and then to descend across such an obstacle as a river.

According to many reports a Portuguese named Gusmao rose from Lisbon in 1709 in an airship, and his arrival in Vienna is gravely described in a contemporaneous tract published there and entitled: *Nachricht von dem Fliegenden Schiffe so aus Portugal den 24 Juni in Wien mit seinem Erfinder glücklich ankommen.*

In 1755 Father Galien of Avignon published

a book called *L'Art de naviguer dans les airs* in which he enunciated clearly the theory of rarefied air-balloons. He states that balloons filled with the air of the upper regions would float in the denser air below, but does not explain the method of filling. The time was now ripe for the invention of the balloon, although other attempts at mechanical flight intervened, notably the flying chariot of Blanchard, who afterwards became a distinguished aëronaut.

After Cavendish had shown in 1766 that hydrogen gas is much lighter than air and Cavallo, who also lived in London, had filled soap-bubbles with hydrogen, the principle of the balloon was demonstrated. It was reserved, however, for the Montgolfier brothers, paper makers of Annonay, near Lyons, to make a practical application of the principle. After some preliminary experiments, a public trial was made on June 5, 1783, and a paper balloon, weighing with the wooden frame around its mouth, 300 pounds, and filled with 22,000 cubic feet of hot air, produced by burning straw, rose more than a mile into the atmosphere. This experiment, the first step in the conquest of the air, excited great interest

and was repeated in Paris two months later by Charles and Robert, who, however, used the newly-discovered hydrogen gas instead of hot air. Benjamin Franklin, then United States Minister to the Court of France, took great interest in the experiments, and amid the pressure of diplomatic and social duties he found time to investigate personally this new invention, of which he at once appreciated the possibilities. Franklin's letters to Sir Joseph Banks, president of the Royal Society of London, give a complete and accurate account of the beginning of aërial navigation, enlivened with the humor and speculation characteristic of the writer. Since these letters are little known, portions of some of them are reprinted from the original press copies owned by the author.

THE FIRST HYDROGEN BALLOON

PASSY, Aug. 30, 1783.

On Wednesday, the 27th Instant, the new aerostatic Experiment, invented by Messrs. Montgolfier, of Annonay, was repeated by M. Charles, Professor of experimental Philosophy at Paris.

A hollow Globe 12 feet Diameter was formed of what is called in England Oiled

Silk, here *Taffetas gommé,* the Silk being impregnated with a Solution of Gum elastic in Linseed Oil, as is said. The Parts were sewed together while wet with the Gum, and some of it was afterwards passed over the Seams, to render it as tight as possible.

It was afterwards filled with the inflammable Air that is produced by pouring Oil of Vitriol upon Filings of Iron, when it was found to have a tendency upwards so strong as to be capable of lifting a Weight of 39 Pounds, exclusive of its own Weight which was 25 lbs and the Weight of the Air contain'd.

It was brought early in the morning to the *Champ de Mars,* a Field in which Reviews are sometimes made, lying between the military School and the River. There it was held down by a Cord till 5 in the afternoon, when it was to be let loose. Care was taken before the Hour to replace what Portion had been lost, of the inflammable Air, or of its Force, by injecting more.

It is supposed that not less than 50,000 People were assembled to see the Experiment, The *Champ de Mars* being surrounded by multitudes, and vast Numbers on the opposite Side of the River.

At 5 o'Clock Notice was given to the Spectators by the Firing of two Cannon, that the Cord was about to be cut. And presently the Globe was seen to rise, and that as fast as a Body of 12 feet Diameter, with a force only of 39 Pounds, could be suppos'd to move the resisting Air out of its Way. There was some Wind, but not very strong. A little Rain had wet it, so that it shown, and made an agreeable Appearance. It diminished in Apparent Magnitude as it rose, till it enter'd the Clouds, when it seem'd to me scarce bigger than an Orange, and soon after became invisible, the Clouds concealing it.

The Multitude separated, all well satisfied and delighted with the Success of the Experiment, and amusing one another with discourses of the various uses it may possibly be apply'd to, among which many were very extravagant. But possibly it may pave the Way to some Discoveries in Natural Philosophy of which at present we have no Conception.

A Note secur'd from the Weather had been affix'd to the Globe, signifying the Time & Place of its Departure, and praying those who might happen to find it, to send an account of its State to certain Persons at Paris. No

News was heard of it till the next Day, when Information was receiv'd, that it fell a little after 6 o'clock, at Gonesse, a Place about 4 Leagues Distance, and that it was rent open, and some say had Ice in it. It is suppos'd to have burst by the Elasticity of the contain'd Air when no longer compress'd by so heavy an Atmosphere.

One of 38 feet Diameter is preparing by Mr. Montgolfier himself, at the Expence of the Academy, which is to go up in a few Days. I am told it is constructed of Linen & Paper, and is to be filled with a different Air, not yet made Public, but cheaper than that produc'd by the Oil of Vitriol, of which 200 Paris Pints were consum'd in filling the other.

It is said that for some Days after its being fill'd, the Ball was found to lose an eighth Part of its Force of Levity in 24 Hours; Whether this was from Imperfection in the Tightness of the Ball, or a Change in the Nature of the Air, Experiments may easily discover. . : .

M. Montgolfier's Air to fill the Globe has hitherto been kept secret; some suppose it to be only common Air heated by passing thro' the Flame of burning Straw, and thereby ex-

treamly rarefied. If so, its Levity will soon be diminish'd, by Condensation, when it comes into the cooler Region above. . . .

P. S. I just now learn, that some observers say, the Ball was 150 Seconds in rising, from the cutting of the Cord till hid in the Clouds; that its height was then about 500 Toises, but, being moved out of the Perpendicular by the Wind, it had made a Slant so as to form a Triangle, whose base on the Earth was about 200 Toises. It is said the Country People who saw it fall were frightened, conceiv'd from its bounding a little, when it touched the Ground, that there was some living Animal in it, and attack'd it with Stones and Knives, so that it was much mangled; but it is now brought to Town and will be repair'd.

The great one of M. Montgolfier, is to go up, as is said, from Versailles, in about 8 or 10 Days. It is not a Globe but of a different Form, more convenient for penetrating the Air. It contains 50,000 cubic Feet, and is supposed to have Force of Levity equal to 1500 pounds weight. A Philosopher here, M. Pilâtre du Rozier, has seriously apply'd to the Academy for leave to go up with it, in order to make some Experiments. He was complimented on

his Zeal and Courage for the Promotion of Science, but advis'd to wait till the management of these Balls was made by Experience more certain & safe. They say the filling of it in M. Montgolfier's Way will not cost more than half a Crown. One is talk'd of to be 110 feet Diameter. Several gentlemen have ordered small ones to be made for their Amusement. One has ordered four of 15 feet Diameter each; I know not with what Purpose; but such is the present Enthusiasm for promoting and improving this Discovery, that probably we shall soon make considerable Progress in the art of constructing and using the Machines.

Among the Pleasanteries Conversation produces on this Subject, some suppose Flying to be now invented, and that since Men may be supported in the Air, nothing is wanted but some light handy Instrument to give and direct Motion. Some think Progressive Motion on the Earth may be advanc'd by it, and that a Running Footman or a Horse slung and suspended under such a Globe so as to have no more of Weight pressing the Earth with their Feet, than Perhaps 8 or 10 Pounds, might with a fair Wind run in a straight Line across Countries as fast as that Wind, and over Hedges,

Ditches & even Waters. It has been even fancied that in time People will keep such Globes anchored in the Air, to which by Pullies they may draw up Game to be preserved in the Cool & Water to be frozen when Ice is wanted. And that to get Money, it will be contriv'd to give People an extensive View of the Country, by running them up in an Elbow Chair a Mile high for a Guinea, &c., &c.

B. FRANKLIN.

THE FIRST AËRIAL VOYAGE BY MAN

Performed by the Marquis d'Arlandes and Pilâtre de Rozier, Nov. 21, 1783, and represented in Fig. 11, reproduced from a contemporary print.

PASSY, Novr 22d, 1783.

. . . Enclosed is a Copy of the *Procés verbal* taken of the Experiment made yesterday in the Garden of the Queen's Palace *la Muette,* where the Dauphin now resides, which being near my House I was present. This Paper was drawn up hastily, and may in some Places appear to you obscure; therefore I shall add a few explanatory Observations.

This Balloon was larger than that which went up from Versailles and carried the Sheep,

&c. Its bottom was open, and in the middle of the Opening was fixed a kind of Basket Grate, in which Faggots and Sheaves of Straw were burnt. The Air rarefied in passing thro' this Flame rose in the Balloon, swell'd out its sides, and fill'd it.

The Persons who were plac'd in the Gallery made of Wicker, and attached to the Outside near the Bottom, had each of them a Port thro' which they could pass Sheaves of Straw into the Grate to keep up the Flame, & thereby keep the Balloon full. When it went over our Heads, we could see the Fire which was very considerable. As the Flame slackens, the rarefied Air cools and condenses, the Bulk of the Balloon diminishes and it begins to descend. If those in the Gallery see it likely to descend in an improper Place, they can by throwing on more Straw, & renewing the Flame, make it rise again, and the Wind carries it farther. . . .

One of these courageous Philosophers, the Marquis d'Arlandes, did me the honour to call upon me in the Evening after the Experiment, with Mr. Montgolfier the very ingenious Inventor. I was happy to see him safe. He informed me that they lit gently, without the

FIG. 11.—First Aërial Voyage.

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least Shock, and the Balloon was very little damaged.

This method of filling the Balloon with hot Air is cheap and expeditious, and it is supposed may be sufficient for certain purposes, such as elevating an Engineer to take a view of an Enemy's Army, Works, &c., conveying Intelligence into, or out of a besieged Town, giving Signals to distant Places, or the like.

The other Method of filling a Balloon with permanently elastic inflammable Air, and then closing it is a tedious Operation, and very expensive; Yet we are to have one of that kind sent up in a few Days. It is a Globe of 26 feet diameter. The Gores that compose it are red and white Silk, so that it makes a beautiful appearance. A very handsome triumphal Car will be suspended to it, in which Messrs. Roberts, two Brothers, very ingenious Men, who have made it in concert with Mr. Charles, propose to go up. There is room in this Car for a little Table to be placed between them, on which they can write and keep their Journal, that is, take Notes of everything they observe, the State of their Thermometer, Barometer, Hygrometer, &c., which they will have more leisure to do than the others, having no fire to

take Care of. They say they have a contrivance which will enable them to descend at Pleasure. I know not what it is. But the Expence of this machine, Filling included, will exceed, it is said, 10,000 Livres.

This Balloon of only 26 feet diameter, being filled with Air ten times lighter than common Air, will carry up a greater Weight than the other, which, tho' vastly bigger, was filled with an Air that could scarcely be more than twice as light. Thus the great Bulk of one of these Machines, with the short duration of its Power, & the great Expence of filling the other will prevent the Inventions being of so much Use as some may expect, till Chemistry can invent a cheaper light Air producible with more Expedition.

But the Emulation between the two Parties running high, the Improvement in the Construction and Management of the Balloons has already made a rapid Progress; and one cannot say how far it may go. A few Months since the Idea of Witches riding thro' the Air upon a Broomstick, and that of Philosophers upon a Bag of Smoke, would have appeared equally impossible and ridiculous.

These Machines must always be subject to

be driven by the Winds. Perhaps Mechanic Art may find easy means to give them progressive Motion in a Calm, and to slant them a little in the Wind.

I am sorry this Experiment is totally neglected in England, where mechanic Genius is so strong. I wish I could see the same Emulation between the two Nations as I see between the two Parties here. Your Philosophy seems to be too bashful. In this Country we are not so much afraid of being laught at. If we do a foolish thing, we are the first to laugh at it ourselves, and are almost as much pleased with a *Bon Mot* or a *Chanson,* that ridicules well the Disappointment of a Project, as we might have been with its Success. It does not seem to me a good reason to decline prosecuting a new Experiment which apparently increases the power of Man over Matter, till we can see to what Use that Power may be applied. When we have learnt to manage it, we may hope some time or other to find Uses for it, as men have done for Magnetism and Electricity, of which the first Experiments were mere Matters of Amusement.

This Experience is by no means a trifling one. It may be attended with important Con-

sequences that no one can foresee. We should not suffer Pride to prevent our progress in Science.

Beings of a Rank and Nature far superior to ours have not disdained to amuse themselves with making and launching Balloons, otherwise we should never have enjoyed the Light of those glorious objects that rule our Day & Night, nor have had the Pleasure of riding round the Sun ourselves upon the Balloon we now inhabit.

B. FRANKLIN.

THE SECOND AËRIAL VOYAGE BY MAN

Ascension of Messrs. Charles and Robert, Dec. 1, 1783, of which a representation from a contemporary print is given in Fig. 12.

PASSY, Dec. 1, 1783.

In mine of yesterday I promised to give you an account of Messrs. Charles & Robert's Experiment, which was to have been made this Day, and at which I intended to be present. Being a little indispos'd, & the Air cool, and the Ground damp, I declin'd going into the Garden of the Tuilleries where the Balloon was plac'd,

not knowing how long I might be oblig'd to wait there before it was ready to depart; and chose to stay in my Carriage near the Statue of Louis XV. from whence I could well see it rise, & have an extensive View of the Region of Air thro' which, as the Wind sat, it was likely to pass. The Morning was foggy, but about one o'Clock the Air became tolerably clear; to the great Satisfaction of the Spectators, who were infinite. Notice having been given of the intended Experiment several days before in the Papers, so that all Paris was out, either about the Tuilleries, on the Quays & Bridges, in the Fields, the Streets, at the Windows, or on the Tops of Houses, besides the Inhabitants of all the Towns & Villages of the Environs. Never before was a philosophical Experiment so magnificently attended. Some Guns were fired to give Notice that the departure of the great Balloon was near, and a small one was discharg'd which went to an amazing Height, there being but little Wind to make it deviate from its perpendicular Course, and at length the Sight of it was lost. Means were used, I am told, to prevent the great Balloon's rising so high as might indanger its Bursting. Several Bags of Sand were taken

on board before the Cord that held it down was cut, and the whole Weight being then too much to be lifted, such a Quantity was discharg'd as to permit its Rising slowly. Thus it would sooner arrive at that Region where it would be equilibrio with the surrounding Air, and by discharging more Sand afterwards, it might go higher if desired. Between One & Two o'Clock, all Eyes were gratified with seeing it rise majestically from among the Trees, and ascend gradually above the Buildings, a most beautiful Spectacle! When it was about 200 feet high, the brave Adventurers held out and wav'd a little white Pennant, on both sides their Car, to salute the Spectators, who return'd loud Claps of Applause. The Wind was very little, so that the Object, tho' moving to the Northward, continued long in View; and it was a great while before the admiring People began to disperse. The Persons embark'd were Mr. Charles, Professor of Experimental Philosophy, & a zealous Promoter of that Science; and one of the Messieurs Robert, the very ingenious Constructors of the Machine. When it arrived at its height, which I suppose might be 3 or 400 Toises, it appeared to have only horizontal Motion. I had a Pocket Glass,

FIG. 12.— Second Aërial Voyage.

FIG. 13.—Jeffries and Blanchard Arriving in France.

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with which I follow'd it, till I lost Sight, first of the Men, then of the Car, and when I last saw the Balloon, it appear'd no bigger than a Walnut. I write this at 7 in the evening. What became of them is not yet known here. I hope they descended by Day-light, so as to see & avoid falling among Trees or on Houses, and that the Experiment was completed without any mischievous Accident, which the Novelty of it & the want of Experience might well occasion. I am the more anxious for the Event, because I am not well informed of the Means provided for letting themselves gently down, and the Loss of these very ingenious Men would not only be a Discouragement to the Progress of the Art, but be a sensible Loss to Science and Society. . . .

Tuesday Morning, December 2.— I am reliev'd from my Anxiety by hearing that the Adventurers descended well near l'Isle Adam, before Sunset. This Place is near 7 Leagues from Paris. Had the Wind blown fresh, they might have gone much farther.

P. S. Tuesday Evening. . . . I hear farther that the Travellers had perfect Command of their Carriage, descending as they pleas'd by letting some of the inflammable Air

escape, and rising again by discharging some Sand; that they descended over a Field so low as to talk with Labourers in passing and mounted again to pass a Hill. The little Balloon falling at Vincennes shows that mounting higher it met with a Current of Air in a contrary Direction; An Observation that may be of use to future aërial Voyagers.

B. FRANKLIN.

To appreciate the ascent of man from the time that he possessed the means of rising freely in the air, we must remember that for centuries he was not only confined to the earth's surface but had not even climbed its high mountains, since not until 1787 did De Saussure reach the summit of Mont Blanc. As soon, however, as the long sought for means of rising without exertion into the air had been discovered men speedily availed themselves of it — namely, first of the Montgolfière or hot-air balloon, and then of the Charlière, or hydrogen balloon, and so rapidly was this done that before the close of the year 1783 — the year that Montgolfier had produced his balloon — M. Charles ascended in a hydrogen balloon 9,000 feet above Paris.

The first persons in England who devoted themselves to aërial navigation were foreigners. Two of them were Italians, the philosopher Tiberius Cavallo, who already in 1782 had showed to a London assembly that soap-bubbles filled with hydrogen will rise, and therefore had almost anticipated the invention of the hydrogen balloon, and the diplomatist Vincent Lunardi, who made some daring balloon ascents in 1784. But the honor of making the first scientific balloon voyage is due to a Bostonian, Dr. John Jeffries. Dr. Jeffries graduated at Harvard College in 1763 and then practiced medicine in England, where he became a loyalist, and during the Revolution was with the British troops. In London he interested himself in aërostation, and, aided by the Royal Society, made a balloon ascent because, he said, "I wished to see the following points more clearly determined: first, the power of ascending or descending at pleasure, while suspended and floating in the air; secondly, the effect which oars or wings might be made to produce towards the purpose and in directing the course of the balloon; thirdly, the state and temperature of the atmosphere at different heights from the earth; and fourthly, by ob-

serving the varying course of the currents of air, or winds, at certain elevations, to throw some new light on the theory of winds in general." A French professional aëronaut named Blanchard had made three ascents in France and one in England, and Dr. Jeffries paid one hundred guineas to accompany Blanchard on his fifth ascent, which was made from London, November 30, 1784. The balloon rose nearly two miles, and descended safely in Kent after an hour and a half. Jeffries' meteorological observations compare favorably with those made until recently; indeed, for nearly a century there was little improvement in the apparatus. The decrease of temperature which Jeffries found, viz. 1° for 360 feet rise, and the decreasing humidity with height agree very well with later observations.

Jeffries and Blanchard undertook a more perilous voyage on January 7, 1785, from Dover across the Channel, landing in the province of Artois, after, so runs the announcement, "we were suspended and floating in the atmosphere two hours over the sea and forty-seven minutes over the land of France." The voyagers were cordially welcomed, and were entertained lavishly in Paris as being, Jeffries

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FIG. 14.—Highest Ascent of Glaisher and Coxwell.

says, "the first who passed across the sea from England into France by the route of the air."

Fig. 13, reproduced from an old print, shows the balloon reaching the land, and on one of the prints is this verse to celebrate the aërostatic alliance:

Deux Peuples divisées pour l'Empire des Mers,
Ne font qu'un aujourd'hui en franchissant les airs,
Présage fortuné de l'union sincère
Qui va regner entre eux pour le bien de la Terre.

Scientific observations in balloons, made in the early part of the last century, under the direction of the French Academy of Sciences, by Biott and Gay-Lussac, added materially to our knowledge of the constitution and properties of the atmosphere, but the first systematic work was done under the auspices of the British Association for the Advancement of Science from 1855 to 1865 by Welsh and Glaisher. In the course of these experiments Glaisher made his famous ascent to the height of what he claimed was seven miles, but which is now generally believed to have been below six miles. Glaisher and his aëronaut Coxwell nearly lost their lives at this time by asphyxiation as depicted in Fig. 14, which is extracted from Glaisher's *Travels in the Air*.

In 1875 an attempt in France to make scientific observations at a great altitude resulted in the asphyxiation of Crocé-Spinelli and Sivel at a height of about 28,000 feet, notwithstanding the oxygen carried to assist respiration.

In 1890 the German Society for the Promotion of Aërial Navigation, aided by the German Emperor, began to collect observations in balloons by such methods as would insure accurate results, which previous aëronauts had not obtained. Professor Berson, who executed most of these ascensions, became known in Germany as "der höchste Mensch" (the highest man) because he had risen higher into the atmosphere than any other human being. In his highest ascent from Berlin on July 31, 1901, he was accompanied by Dr. Süring, and, aided by the respiration of oxygen, a height of about 34,000 feet was reached, which constitutes the present record, as seen in Fig. 1. A very large balloon is required, because to rise to such a height, where the atmospheric pressure is only a quarter of that at the ground, the balloon must be able to lift itself when partially filled with gas and, accordingly, the balloon, which could contain nearly 300,000 cubic feet, was two-thirds filled with hydrogen-gas, and car-

FIG. 16.—*Ballon-Sonde* Rising from St. Louis.

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ried ballast to the amount of 8,000 lbs. An ascent in this great balloon had been made from Charlottenburg, a suburb of Berlin, a few weeks before, by the same aëronauts, accompanied by Dr. von Schrötter, a physiologist. The balloon in this case was filled with 247,000 cubic feet of illuminating gas, and reached a height of 24,000 feet. This ascension was witnessed by the author, and Fig. 15 shows the basket of the *Preussen,* as it rose with many bags of ballast clustered around it.

The French in 1893 found a method of bringing back supremacy to the native land of the balloon without risk of life or limb by the so-called *ballons-sondes,* which carried only self-recording instruments. These were ordinary balloons, which, after rising very high, drifted to a great distance as the gas escaped slowly. Dr. Assmann, a German, made an improvement by substituting small closed balloons of rubber which burst by the expansion of the hydrogen gas within, on reaching their extreme altitudes, and allow the instruments to be borne to the ground by parachutes. These balloons were mentioned in Chapter I, and Fig. 16 shows one of those employed by the author at St. Louis as it is rising.

With the invention of the balloon it was seen that captive balloons could render important service in warfare in determining the location of troops and in disseminating orders by signals, while free balloons would enable communication to be maintained across the enemy's lines. Fig. 17 from a contemporary print shows Coutelle in a captive balloon observing the Austrian troops at the battle of Fleurus in 1794. This method was also successfully practiced in 1861–2 during the American Civil War, while during the Franco-Prussian War of 1870–1 besieged Paris communicated with the outside world by means of free balloons. To-day a balloon corps is attached to the armies of all the great powers for the purpose of directing the fire of the artillery. Kite balloons, of type illustrated in Fig. 18, are used for this purpose. They are anchored obliquely like a kite so that the wind, instead of driving them to the ground, tends to lift them higher and by blowing into an interior air-sack preserves their cylindrical shape. They have proved to be of great value during bombardments of intrenched positions and were used successfully by the British fleet at Gallipoli. They must, however, be supported by an air

FIG. 18.— An American Kite-Balloon.

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service equal to that of the enemy or they will be quickly destroyed by bombs or gun-fire from hostile airplanes. The dirigible balloon will be described in another chapter.

Another use for the balloon is in exploration and one of the most conspicuous examples was the daring attempt of Andree eighteen years ago to reach the North Pole from Spitzbergen, by utilizing the prevailing southwest winds while he kept the balloon at the height of the drag-rope, and this he thought could be done for several weeks. No news was received after the first day or two and it is certain that Andree and his two companions perished miserably. The Alps and the Mediterranean, however, have both been crossed several times in a balloon.

Ballooning as a sport has recently come into favor, and dates from the foundation of the German Aëronautical Society in 1881, which was, however, organized mainly for scientific work. The French Aëro-Club was founded in 1898 and at once became a success in the land where the balloon originated and had always been popular, but it was the Paris Exposition of 1900 that gave an impetus to ballooning as a sport. During the Exposition 158 ascen-

sions took place from the Aëronautic Park at Vincennes without the slightest accident. Balloon racing has been stimulated by contests for the Gordon Bennett Aëronaut's Cup to be awarded annually for the longest air-line distance without intermediate landings, and which has been competed for eight times. In the first race in 1906 it was won by Lieut. Lahm, U. S. A., who went from Paris to England, a distance of 402 miles. As the winner was an American the scene of the contest in 1907 was transferred to St. Louis, and most of the balloons, by utilizing the upper westerly wind, traveled into the states bordering the Atlantic Ocean. The winner was the German balloon *Pommern* with Herr Erbslöh as pilot, his assistant being Mr. Clayton of the Blue Hill Observatory, and they were only stopped by the coast of New Jersey, 872 miles from St. Louis. The next year several of the contestants starting from Berlin narrowly escaped death from falling to the ground or into the water, but the winner, Col. Schaeck, representing Switzerland, crossed the Baltic and landed in Norway after a voyage of 73 hours. In 1909 the race was won by a representative of the United States, Mr. E. W. Mix, who reached Gustovo,

FIG. 15.— Ascent of *Preussen*.
See page 61.

FIG. 17.— Captive Balloon at Battle of Fleurus.
See page 62.

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Russia, near Warsaw, a distance of 697 miles from Zurich. In the race starting from St. Louis in 1910, the Gordon Bennett Cup was for the first time successfully defended. Mr. Alan R. Hawley, after a record breaking flight of 1355 miles, landed in the wilderness at Chicoutimi Woods, Quebec, so far from civilization that it was many hours before he could telegraph a report of his safety. Germany won the cup in 1911, Lieut. Gericke traversing the 468 miles between Kansas City and Holcombe, Wisconsin. The next year the distance record was broken again; M. Maurice Bienaimé won for France by traveling the 1364 miles between Stuttgart, Germany, and Kiazan, Russia, near Moscow. The 1913 race was relatively unsuccessful from the point of view of distance covered. It was won by Mr. Ralph Upson, of the United States, who tried the dangerous expedient of drifting out over the Atlantic Ocean and back across the English Channel into England. Since 1913 there have been no races, but when the war ends this sport will doubtless come into favor once more.

The first ascent by man in a balloon outside France, being the second time that hydrogen gas was used for the purpose, seems to have

been in America, namely in Philadelphia, on December 28, 1783, when, through the initiative of Messrs. Rittenhouse and Hopkinson, a carpenter named Wilcox was lifted a short distance by several small balloons filled with hydrogen. The author, however, has been unable to obtain any particulars of the experiment, and what is usually called the earliest American ascension was made in Philadelphia on January 9, 1793, by J. P. Blanchard, the French aëronaut, who, it will be remembered, had already taken up the first American in England. After this, his 45th ascension, Blanchard was received by President Washington, who is reported to have witnessed it. The most famous American aëronaut is John Wise, who executed no less than 440 ascents in the forty years after 1835, and in one of them went from St. Louis to northern New York, a distance of 809 miles, in 20 hours, but afterwards lost his life in attempting another long voyage.

The Aëro-Club of America, founded in 1905, is the parent of numerous local organizations to promote ballooning as a sport. There is, however, a growing tendency among the members to become interested in the dirigible

balloon and the aëroplane, and the fact that gasoline motors are used both for aviation and automobiling tends to affiliate the aëro clubs with the older automobile clubs.

In Germany the various aëronautical organizations have been amalgamated in a national Union, while international aëronautic sport is regulated by a Federation, founded at Paris in 1905, and composed of representatives of the chief aëro clubs of the world. Scientific and technical questions are considered by the Permanent International Aëronautical Commission, which was formed in 1900, and holds frequent meetings in Paris.

## CHAPTER III

### THE DIRIGIBLE BALLOON

No sooner was the balloon invented than attempts were made to render it independent of the wind and to go in any desired direction. We have seen that Benjamin Franklin, in describing the first balloon voyage by man in 1783, shrewdly suggested "that perhaps mechanic art may find easy means to give them [balloons] progressive motion in a calm and to slant them a little in the wind." A definite conception of the dirigible balloon, which was not realized in practice for a century, was embodied in a letter written to Benjamin Franklin on May 24, 1784, in which the writer, Francis Hopkinson of Philadelphia, proposes to make the balloon spindle-shaped and to drive it by a wheel at the stern. This wheel, it is explained, should consist of vanes or fans of canvas whose planes should be considerably inclined with respect to the plane of its motion, exactly like the wheel of a smoke-jack. Blanchard, of whom we have had occasion to speak

several times, probably was the first in 1784 to apply a species of oars to the basket of a hydrogen balloon but without being able to effect any change in its direction. It was no doubt Blanchard also who induced our countryman, Dr. Jeffries, to try a similar appliance in their balloon-ascension in England later in the same year, one of the objects of this ascension being, according to Jeffries' account, already quoted, "to see the effect which oars or wings might be made to produce towards this purpose [ascending or descending at pleasure] and in directing the course of the balloon."

If the idea of rendering the balloon obedient to its helm by mechanical means dates from the invention of the balloon, that of utilizing favorable currents of air, which was described in Chapter I, is quite as old. While it is true that an aërostat floating freely in a current of air remains in a calm and, therefore, sails would be useless to change its direction, yet, if by a rope trailing on the ground, its velocity is checked, then it may be possible for a suitably arranged sail to alter the course of the balloon with reference to the direction of the wind. Also, since a vertical motion of the balloon produces a relative wind up or down-

wards, by means of oblique planes a lateral motion of the balloon, differing from the wind, may be obtained by its rise or fall. To avoid a loss of either gas or ballast it was attempted to produce a rise or fall of the balloon by means of paddles rotated by the aëronaut.

In 1784 General Meusnier, of the French Academy, made designs for a balloon which had the elements of the modern dirigible, namely, an elongated form and an envelope outside the gas-bag which could be filled with compressed air to maintain the shape of the bag. If more air was forced into the envelope the balloon would become heavier and descend, but if it was desired to rise, the air would be allowed to escape and the gas to expand to its original volume. Supposing there are currents at different heights which differ in direction, the one which corresponds most nearly with the desired route can be chosen, and to enter these currents the more easily, General Meusnier proposed to equip his balloon with vanes set obliquely on an axis which was to be turned by hand. This device [1] was virtually a

[1] Already described two months previously, by Hopkinson in America.

screw-propeller and it was long before the screw as a means of propulsion in water had been suggested. The first elongated balloon was constructed by the brothers Robert, who had aided M. Charles with the first hydrogen balloon. Its envelope, made of varnished cotton, 52 feet long and 32 feet in diameter, was filled with pure hydrogen gas. Below hung a light wooden car, 16 feet long, from which six wings, in the form of oars, were to be worked to give the balloon motion, and a large rectangular oar at the rear acted as a rudder. The first trial was made in the Park of Saint Cloud on July 15, 1784, with the Duke of Chartres as a passenger, and a second trial in Paris was successful in producing a deviation of 22 degrees from the line of the wind.

Numerous airships of all kinds were projected in Europe during the next sixty-eight years, but few of them were of rational design and none of those tried achieved success. Although both the spherical and elongated balloon are claimed to have been invented and developed in France, yet, as we have seen, the idea of mechanical propulsion was suggested by Benjamin Franklin in 1783, and, according to the late Professor R. H. Thurston, a cigar-

shaped balloon, driven by a screw-propeller, was patented in 1820 by Rufus Porter, an American. A model exhibited in New York between 1835 and 1840 was reported in the newspapers as flying rapidly and sustaining itself for a considerable time.

A real advance lay in the application of an artificial motor to the balloon, which was first done by Henri Giffard in 1852. His balloon had a gas-bag, pointed at either end, 144 feet long and 39 feet in diameter, and was driven by a screw-propeller turned by a three horse-power steam engine.

The small power, the lack of rigidity in the supports of the car and the deformation of the envelope itself, all contributed to the want of success of this balloon, which attained a speed of but seven miles an hour. Giffard, however, constructed a larger balloon and studied the plans for a gigantic one. During the Paris Exposition of 1878, he operated the largest captive balloon ever made, which could take up forty people at once. After the siege of Paris, Dupuy de Lôme, the eminent engineer, built an elongated balloon in which he preserved the form of the envelope, suspended rigidly the car, and avoided the resistance of

the customary netting. Fearing to have fire near inflammable gas, Dupuy de Lôme employed eight men to work his screw-propeller, which gave this balloon a less speed than that of Giffard.

The dirigible balloon of Gaston Tissandier in 1883, in which the power was furnished by an electric storage battery, marked another step forward, but, although the speed attained was greater than that of his predecessors, it was not sufficient to bring the balloon back to its starting point.

The problem of the dirigible balloon was now taken up by the French War Department, and at the Central Establishment for Military Aëronautics at Chalais-Meudon elaborate experiments were carried out by Captain Charles Renard upon the resistance of the air to different bodies, the strength of materials, and the weight of motors. In 1884, just a century after the first elongated balloon had tried to overcome the wind, the balloon the *France,* designed by Captain Renard and his collaborator, Lieutenant Krebs, accomplished the unprecendented feat of returning to its starting point. During the ensuing year, this balloon, which attained a speed of about

fourteen miles per hour, was able to return to its house at Chalais-Meudon five out of the seven times that it was tried, which were days of light winds. Fig. 19 shows the *France* as it appeared over Paris on September 22, 1885. This balloon embodied the best features of its predecessors. It was elongated and contained the *ballonet* of Meusnier; adopting the ideas of Dupuy de Lôme, the net was replaced by a close-fitting covering with crossed suspension cords and the propeller and rudder were large; and, following Tissandier's example, an electric motor was used. The novelties were the unsymmetric form of the envelope, with the large end in front, which gave stability of motion, the division of the *ballonet* into compartments, and the great length of the car, which enabled it to be brought up near the envelope, thereby diminishing the resistance due to the cordage. But the greatest improvement was the employment of a nine horse-power motor, which was much more powerful than any hitherto used in a balloon, and which, owing to a new storage battery invented by Captain Renard, had the unprecedented lightness of 100 pounds per horse-power. The length of the gas-bag was 165 feet, the diame-

FIG. 19.— The *France* over Paris.

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ter 27 1-2 feet, and the propeller, placed in front of the car, counterbalanced the weight of the rudder behind.

We now come to the modern dirigible balloon, in the success of which the chief factor has been the vast increase in efficiency and the decrease in weight of the gasoline motors developed by the automobile makers. The conditions necessary for a dirigible balloon were formulated by the late Colonel Renard, who was the best authority on the subject, as follows: —

1. An elongated form, similar to that of a boat.

2. Maintenance of shape by means of an internal sack, or *ballonet,* which permits loss of gas to be replaced by air.

3. Completion of the longitudinal stability, already partially secured by the *ballonet,* by a rigid suspension of the car.

4. A propeller of suitable size, driven by as powerful a motor as is consistent with weight.

5. A rudder at the rear, permitting changes of direction.

For a balloon to be dirigible in all directions it is necessary that its own speed, relative to

the ground, should be greater than that of the average winds in which it must operate. Evidently, then, a balloon will be dirigible on certain days and not on others, whatever is its proper speed, and it will be more often dirigible in proportion as its speed is greater. According to observations 100 feet above a plateau near Chalais-Meudon, in the neighborhood of Paris, the wind is less than 22 miles per hour on seven out of ten days, so that a balloon having a proper speed of 28 miles an hour could maneuver in all directions 81 times in 100, and could progress 5½ miles an hour against the wind at least 71 times in 100. Since the frequency of a wind of about 20 miles per hour at Chalais coincides nearly with that at Blue Hill, as stated in Chapter I, it follows that the speed-qualifications for dirigible balloons operated at low levels are about the same on the two continents. Colonel Renard believed that the conquest of the air would be practically achieved whenever a dirigible balloon could be constructed having a velocity of twenty-eight miles per hour, which it could maintain during ten or twelve hours. We shall see later how nearly these conditions have been fulfilled by perfecting the motors

and by diminishing the resistance of the balloon to the air.

The gasoline motor as applied to automobiles had been improving in efficiency and decreasing in weight during the ten years following Renard's experiments, and in 1900 a young Brazilian, Alberto Santos-Dumont, first applied one to a small balloon. After constructing six balloons, in which he did not profit by the experiences of his predecessors, he won a prize of $20,000 offered by M. Deutsch de la Meurthe, by sailing from Saint Cloud around the Eiffel Tower, a distance of three and one-half miles, and returning within half an hour, a feat which was accomplished, after several trials, on October 19, 1901. The envelope of this balloon was 108 feet long and 20 feet in diameter, with a gasoline motor which could develop 18 or 20 horse-power. The speed over the ground in the trial quoted was, according to the figures given, 14 miles per hour, but, on account of the wind, the actual velocity through the air was about 19 miles per hour. While this was somewhat faster than the *France,* it must not be forgotten that the latter, the first successful dirigible balloon, or aëronat, was constructed by Captain

Renard six years previously. Santos-Dumont's great service consisted in popularizing the motor-balloon and in inducing the French government to take up the aëronat again. Santos-Dumont constructed no less than 14 balloons of various sizes and in 1904 he came to America with one of them as the only serious competitor for the prize of $100,000 offered by the Louisiana Purchase Exposition. Santos-Dumont had been at St. Louis during the previous year in order to assist a committee, of which the author was a member, to formulate rules to govern the competition. Just before the trials his balloon was mutilated in an unexplained manner within the Exposition grounds, and Santos-Dumont at once returned to Paris. In his many ascensions he suffered serious accidents but always escaped without injury. Other experimenters with dirigible balloons were not so fortunate and two met with fatal accidents. A compatriot of Santos-Dumont, named Severo, and his assistant, were killed by their motor balloon taking fire during its trial over Paris in 1902, and later in the same year De Bradsky and his mechanician were also killed by the car of their aëronat breaking away when above Paris.

The balloon of Santos-Dumont was not suitable for military purposes and that end was attained a few years later by the Lebaudy brothers, rich French sugar-refiners. In 1899 they commissioned an engineer named Julliot to design a dirigible balloon, and the first model, called the *Jaune,* from the yellow rubber cloth, made in Germany, which composed the gas-envelope, was completed in 1902. It formed with its car a vertical triangle, the apex pointing downward with the center of gravity above. Julliot endeavored to secure stability when in motion and to avoid the injurious oscillations that Colonel Renard had shown were set up whenever a certain velocity was exceeded and which, in the case of the *Jaune,* was 23 miles per hour. Consequently, planes of incombustible fabric were placed underneath the balloon and were afterwards extended far behind the rudder so as to make the airship a combination of balloon and aëroplane.

To maintain the shape of the gas-bag, which is essential in all non-rigid envelopes driven against the wind, the *ballonet,* proposed more than a century before by General Meusnier, was employed. This is a large pocket of rubber fabric within the gas-bag, which can be

filled with air from a motor-driven blower in the car. Valves in both *ballonet* and gas-bag open at pre-determined pressures, and as the balloon rises the pressure of the external air diminishes and the gas tends to expand, thereby compressing the air in the *ballonet*, which escapes by the valve. When the balloon descends the gas contracts and under the increased external pressure both gas-bag and *ballonet* become flabby until the blower replaces the air which had been expelled and thus the rigidity and shape of the balloon are maintained. The *Jaune*, having a length of 183 feet, a diameter of 32 feet, and holding 80,600 cubic feet of hydrogen gas, was propelled by a 40-horse-power Daimler motor, which turned twin-screws, at a maximum speed of 26 miles per hour, this being reduced to an average speed of 14 miles in one hour. In the 29 voyages undertaken, the balloon returned to its starting point 28 times. In 1904 the *Lebaudy*, a larger balloon of the same type was built, and after fulfilling various tests, was accepted by the French War Department. During these trials the balloon carrying three persons, went from Moissons to Meaux, an air-line distance of 57 miles, in two hours and thirty-five min-

utes, and from Meaux to Chalons, 61 miles, in three hours and twenty-one minutes. The balloon becoming damaged was sent to the fortress of Toul for repairs, after which it made a series of successful reconnaissances and on its seventy-second ascension carried five persons.

This type of balloon having been adopted by the French government for military purposes, the *Patrie* was brought out in 1906. Its gas-bag was 197 feet long, this being approximately six times its maximum diameter, which occurred about two-fifths of the length from the front. The cigar-shaped form of Renard was retained, but while the *Lebaudy* was pointed at the rear to secure the least resistance, in the *Patrie* horizontal and vertical planes placed there added to the stability and so the stern of the balloon became ellipsoidal. The volume at first was 111,250 cubic feet, but later its volume was increased by 17,660 cubic feet. The *ballonet* had a volume of approximately one-fifth the total contents, in order to permit a height of nearly one mile to be attained (since there the reduction in air-pressure is one-fifth), and to descend, while keeping the gas-bag rigid, the air being

pumped into the *ballonet* as the gas was let out. A feature of the *Patrie* was the long suspension of the car, which hung from an elliptical frame of nickel-steel tubes and could carry seven persons. For transportation the metal frame could be quickly detached from the bag and the frame taken apart. The boat-shaped car contained a Panhard and Levassor four-cylinder motor which turned two eight-foot six-inch propellers 1000 to 1200 times a minute. In operation the pilot stood at the front of the car and the engineer at the rear, while the officers had at their disposal a tele-photographic apparatus and a 100-candle-power acetylene searchlight. Besides the fixed horizontal and vertical planes, which enabled the airship to maintain a constant level and to move in a straight line without deviating to the right or left, a movable horizontal plane, above the car and near the center of gravity, counteracted the rise and fall of the balloon due to change in volume of the gas, or other causes, and could also produce these motions and so reduce the loss of gas and ballast to a minimum.

The perfected *Patrie* made a number of long trips at an altitude of 2,500 to 3,000 feet and on November 23, 1907, went from Chalais-

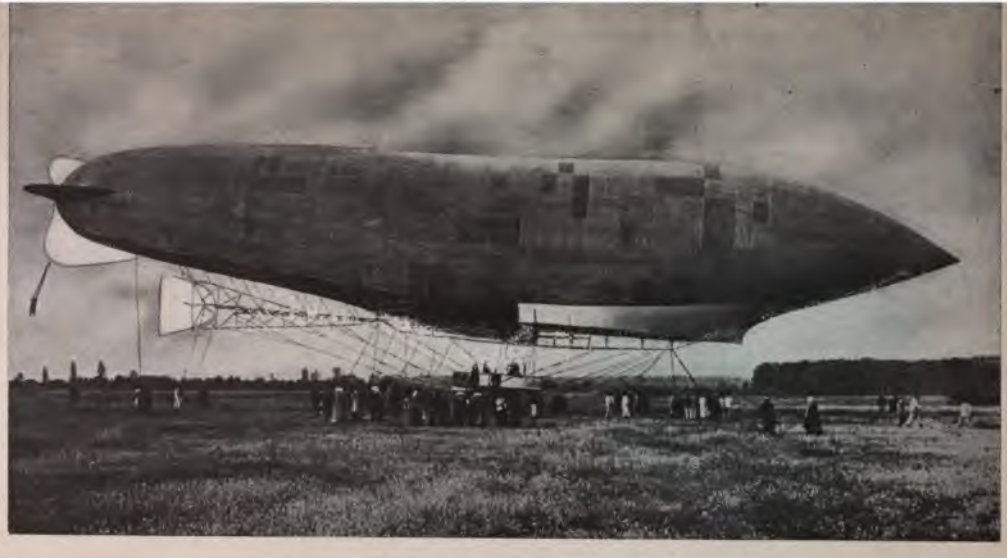

FIG. 20.—Military Dirigible the *République*.

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Meudon to Verdun, a distance of 187 miles, in six hours and forty-five minutes, against a light northeast wind. A few days later an accident to the engine necessitated a landing, when a gale tore the airship from the company of soldiers who were holding the lines, and it drifted over France and Ireland and out to sea. Another similar balloon called the *République* was at once constructed by Julliot for the French government, differing only from the ill-fated *Patrie* in having 2,000 cubic feet more gas capacity, which gave a total lift of 2,700 pounds for passengers, ballast, fuel, etc. This dirigible is shown in Fig. 20. When inflated with pure hydrogen it can carry eight men a distance of 500 miles without stops, and the 80-horse-power motor gives it a speed of about 28 miles an hour.

Another notable airship was the *Ville de Paris,* built at the expense of M. Deutsch de la Meurthe, a patron of aëronautics in France. The first model, which was constructed from designs of the engineer, Tatin, not proving successful, another one was built by Surcouf, the well-known balloon maker, who followed in many respects the ideas of Colonel Renard. After the loss of the *Patrie,* M. Deutsch of-

fered his balloon to the French government, which accepted it. The gas-bag was 200 feet long, with a diameter of 34½ feet, which gave the same ratio as in the *France* and the *Patrie*, the maximum diameter being, as in the last-named balloon, about three-eighths of the distance from the front. The middle section was cylindrical, with conical sections in the front and rear. At the extreme rear was another cylindrical section, around which clustered four little cylinders, each surmounted by a still smaller one and all connected with the main reservoir. These cylinders replaced the horizontal and vertical planes of the *Patrie*, which maintained stability, but offered more resistance to the air. Motion up or down was obtained by two pairs of horizontal planes, as in the *Patrie*. A 70-horse-power "Argus" engine drove a two-bladed wooden propeller, placed in front of the car, where it worked in undisturbed air as in the *France*. It turned only 250 times a minute, on account of its large diameter of 20 feet and pitch of 26 feet, and the proper speed of this balloon probably did not exceed 25 miles per hour.

The *Clément-Bayard*, similar in design to the *Ville de Paris*, was constructed by the Astra

Society, and sold to the Russian government for $40,000. It had a slightly greater cubic contents than the *Ville de Paris,* and was distinguished from it by the rear gas-bags, which gave stability, being conical and therefore presenting less resistance to motion. The car, built of steel tubing, was inclosed in aluminum plates, and could accommodate eight persons. A Clément-Bayard motor of 100 horse-power drove a wooden screw, 16 feet in diameter, at 380 revolutions a minute, the screw being placed in front of the car. This balloon, shown in Fig. 21, may be regarded as the most perfect French type of its time, and attained about 30 miles per hour. In fact, a round trip from its shed at Sartrouville, over a distance of 125 miles, was made at a speed of 27 miles per hour. A condition of its acceptance by the Russian government was that it should ascend to a height of seven-eighths of a mile by its own power.

After 1909, when the *Clément-Bayard* was constructed, there were no radical changes in French military dirigibles. Each year improvements were made in size and construction, until by 1914 efficient war machines were in use. What they were like we know from

occasional photographs, but beyond that we have little information. It was reported at the outbreak of the war that French military dirigibles held the speed record and that *L'Adjutant Vincenot,* about 320,000 cubic feet in volume, held the duration record of 35 hours 19 minutes. The only dirigible of the rigid type constructed by France is oddly enough the best known of all. Yet even in this case, the data given at different times are so radically different as to lead to a suspicion that several models were in existence at the outbreak of the war. This French rigid dirigible is the *Spiess.* Its length is given as both 288 feet, 9 inches, and 371 feet, 6 inches; while the corresponding diameters are 39 feet, 4 inches, and 41 feet, 9 inches. A brief description accompanies the smaller dimensions. According to it, the *Spiess* was built of wood. The volume is given as 293,000 cubic feet, and the lift as about 9 tons. There were two cars suspended beneath the hull, each containing a six-cylinder water-cooled Chenu motor of 180 horse-power. Four two-bladed propellors gave the airship a speed estimated at 48 miles per hour.

We will now proceed to Germany, where we saw, in the last chapter, twenty years ago ap-

FIG. 21.—Dirigible the *Clément-Bayard.*
See page 85.

FIG. 24.—The Passenger Zeppelin *Schwaben.*
See page 95.

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plications of the free and captive balloon to scientific and military purposes. The first German dirigibles were not successful. Dr. Wölfert's motor-balloon, while being tried at Berlin in 1897 was set on fire by the gasoline-motor and both Wölfert and his mechanic perished. In the same year an aluminum balloon, whose construction was begun several years before by an Austrian engineer named Schwartz, met with disaster at Berlin. The idea of using a metal gas-receptacle was proposed by a Frenchman, Marey-Monge, in 1842, and the project was revived when aluminum could be provided cheaply. Count von Zeppelin, a former general in the Germany army and adjutant to the King of Wurtemburg, conceived the idea of constructing a large and rigid airship, which should preserve its shape under all conditions. This idea was not favorably received by the Prussian Ministry of War, and Count von Zeppelin accordingly organized a company to build the largest of all airships. A site was given by the King of Wurtemburg at Manzell, near Friedrichshafen, on the shore of Lake Constance, and in 1898 a great floating shed was anchored at its front end, which, accordingly thus always faced the

wind. In the shed a strong aluminum frame, having 16 sides, but of general cylindrical appearance, 420 feet long and 39 feet in diameter, with bomb-shaped ends, was put together. The interior was divided into 17 compartments, each holding an ordinary balloon, which had a combined volume of 390,000 cubic feet. The metal frame was covered with rubber cloth coated with pegamoid, and this skin not only furnished a smooth surface and protected the gas-bags against damage and the influence of weather, but the insulating air-space decreased the changes of temperature, which cause a rise or fall of the balloon according as the gas is expanded or contracted. Thirty-three feet below the frame were hung two aluminum boats, each provided with a 16-horse-power Daimler benzine motor. The scheme of duplicate motors, to prevent stoppage through accident to one of them, originated with Count von Zeppelin and was adopted by other constructors. The four-bladed air propellers, with a diameter of only about four feet and rotating 1,000 times a minute, were placed right and left of the motors, near the center of pressure and somewhat below the longitudinal axis of the balloon. Vertical and horizontal planes served to

maneuver sidewise and up or down, but to regulate the equilibrium and to raise and lower the prow there was a heavy counterweight, which could be shifted on a horizontal truss under the balloon. The surface of the lake furnished a level surface for launching this long rigid structure, while the floating shed afforded shelter. The filling of the 17 balloons required 2,600 cylinders of compressed hydrogen gas and the preliminary trials were not commenced until July, 1900. A series of accidents prevented them from being successful, but in October a speed of 19 miles an hour was obtained, the greatest hitherto attained by any motor-balloon, and when it is remembered that this airship equaled in size many ocean steamships and exceeded most of them in speed, although possessing engines of only 32-horse-power, the result must appear extraordinary. It will be noticed that some of the ideas which have been used to secure safety at sea, namely, the division into compartments and the duplication of the engines, were applied to this balloon. The great size of the *Zeppelin,* provided it can be controlled, is an important factor in its success, for, as Mr. Chanute predicted several years ago, since the cubic con-

tents and lift increase with the cube of the dimensions and the weight in a far smaller ratio, a balloon of this size should be able to lift a very powerful motor and attain a speed of thirty or more miles an hour, which, as we shall see, has recently been done. Having spent a large personal fortune on his experiments, Count von Zeppelin in 1903 sought unsuccessfully, through the writer, to have another airship constructed by the St. Louis Exposition which had advertised aëronautics as a feature.

Five years elapsed before the Count was able to secure the means to build a second airship, improved in almost all respects, but especially by an increase of the motive power to 170-horse-power and enlarged propellers. In front and behind three vertical planes helped to steer in a horizontal direction, and between them and the car horizontal planes facilitated changes in a vertical sense, the steering being effected from the front car.

The trial flights in the winter of 1905–6 were executed under adverse conditions, and after a landing the airship was damaged by a gale. Undaunted by his new misfortune, Count von Zeppelin built No. III, having the same length as the last, but more powerful

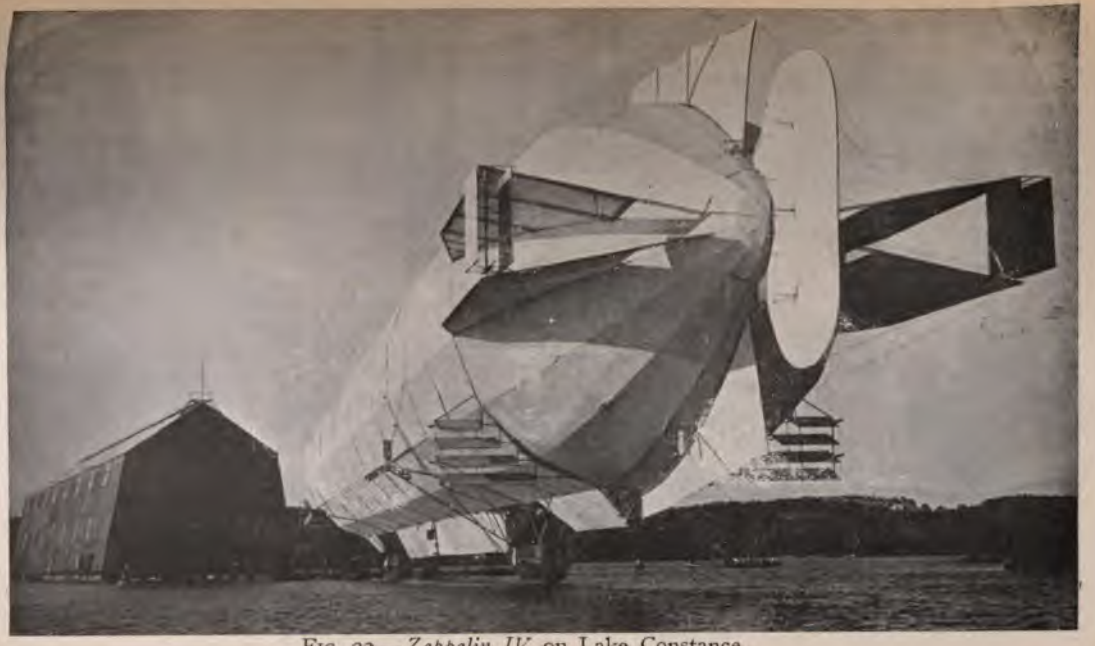

FIG. 22.—*Zeppelin IV* on Lake Constance.

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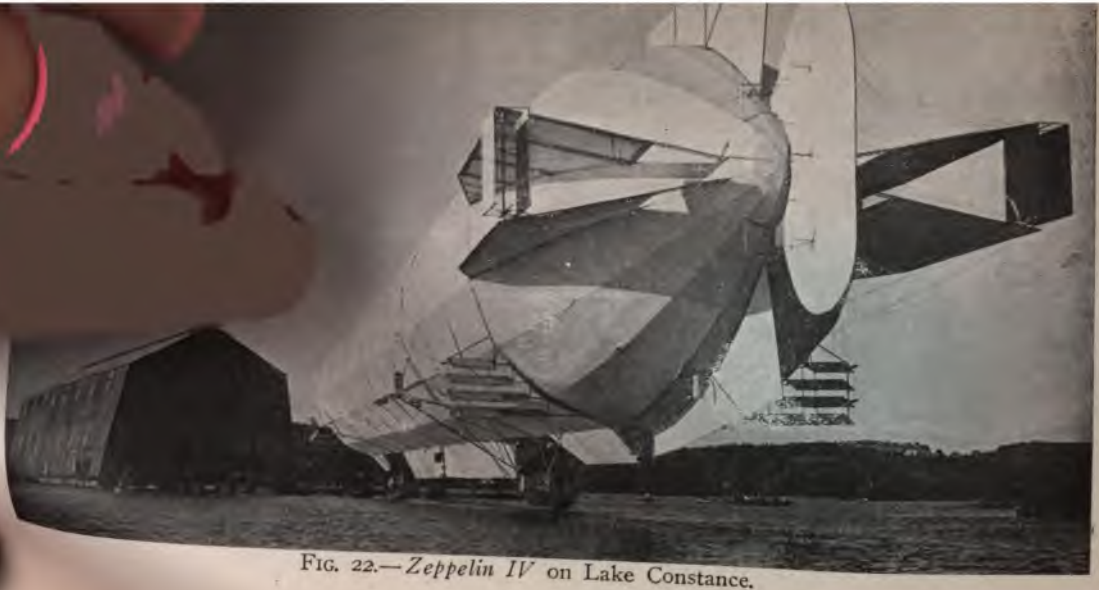

FIG. 22.—*Zeppelin IV* on Lake Constance.

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motors, and possessing a carrying capacity of eight persons and 5,500 pounds of ballast, etc. The tests in October, 1906, were entirely successful, for according to the official report to the Minister of War, the airship was extremely stable and easily turned, while its speed (namely, 30 miles per hour) was greater than that of other airships. A height of half a mile was reached, and eleven persons were carried 67 miles in two hours and seventeen minutes, which considerably surpassed the performance of the French military balloon. The German government now lent financial aid to enable the advantage of the rigid system of construction to be demonstrated. A new floating shed was erected and in it another airship was constructed, which was successfully tried in the autumn of 1907 and made one continuous run of eight hours. Modifications suggested by experience were introduced in Model IV, of which a photograph is given in Fig. 22. This balloon had a length of 446 feet, with a maximum diameter of 42½ feet, and its 16 compartments could contain 460,000 cubic feet of gas, which gave a total gross lift of 16 tons. Each boat-like car was provided with a 110-horse-power Daimler motor that drove a

pair of three-bladed propellers about 15 feet in diameter. A third car for passengers only was built into the keel under the center of the framework. The balloon is towed from its shed, while resting on its floating cars, and ordinarily descends again on the lake as seen in Fig. 22. The steering apparatus at the stern was considerably enlarged and, with the steadying planes at the sides, are shown in the picture. A huge vertical rudder was attached to the extreme end of the rigid frame and an additional rudder placed between each set of horizontal planes on the sides. For vertical steering there were four sets of movable horizontal planes, working like a shutter, near the extremities of the frame and at about the height of the propellers. Early in the summer of 1908 this balloon made a series of voyages, and in a notable one on July 4, crossed the mountains to Lucerne and Zurich and returned over Lake Constance. The closed circuit, shown in Fig. 23, measured 235 miles and was accomplished in twelve hours, giving 20 miles an hour as the average speed of the balloon. On August 4, quite unexpectedly, the great 24-hour voyage required for the acceptance of the balloon by the government, was undertaken.

FIG. 23.—Voyage of *Zeppelin IV*.

It was intended to follow the Rhine to Mainz and return in a straight line to Friedrichshafen. Two landings for repairs were made, and during the second one, in the vicinity of Stuttgart, a squall tore the airship from its moorings and carried it into the air where it was set on fire, probably by an electrical discharge, and in a few minutes was completely destroyed. Thus within a year, through similar accidents, both France and Germany lost their best military airships.

The accident had no bearing on the merits of the rigid system of construction as exemplified in the *Zeppelin,* which showed stability and dirigibility in both a vertical and horizontal direction and the possibility of landing on dry land. At its last landing the balloon had been in the air 20 hours and 45 minutes and had traveled 378 miles.

The enthusiasm of the German people, which had been aroused by the voyages of the monster airship, manifested itself after its destruction in an outburst of patriotism, and the subscriptions which were opened in all parts of Germany to aid Count von Zeppelin, soon amounted to $1,500,000. This was paid to a Zeppelin Society which acquired a great plant at Friedrichshafen in order to build airships on a large scale.

In spite of repeated disasters, construction was carried on year after year, and at the outbreak of the war a large fleet was in operation.

In 1910, the German Airship Company was formed and passenger lines established. Three years later the Company's report shows that 826 cruises had been made, 17,222 passengers being carried approximately 64,172 miles in an aggregate of 1835 hours in the air. These

passenger-carrying airships, which made their trips regularly, offered the passengers cabin and restaurant service and practically all the luxuries of travel obtainable in Pullman cars. Experience showed that this service could be maintained 340 days in the year. There was always, however, the danger of a sudden storm which would wreck the giant dirigible before it could be housed. This was the fate which overtook the *Schwaben* and which left one *Zeppelin* curled like a huge metallic snake around the base of a little hill. The danger of fire was also a menace. On October 17, 1913, the newest and largest of the German naval *Zeppelins,* the *L-2,* was destroyed in midair during her trial trip. Spectators who had been watching the impressive maneuvers from below suddenly saw the great gas bag burst into flames and then fall. A second or two later, the reverberating sound of a terrific explosion reached them. Every inch of the covering disappeared in an instant. Then, as the fire reached the gasoline tanks, filled with two tons of fuel, a second and more violent explosion was heard. Before the echoes of it had died, the wreck of Germany's greatest dirigible lay on the ground, a mass of tangled wires and

glowing girders. Even this disaster proved, in the words of the Kaiser himself, to be "only a spur to renewed exertions."

While the *Zeppelins* were developing in the manner just described, a number of other types came into being in Germany. As early as 1906, Major von Parseval, formerly of the Bavarian Army, embodied in a non-rigid gas-bag the principles of the kite balloon which he invented. This dirigible and its successors were built by the Luft-Fahrzeug-Gesellschaft (commonly known as the "L. F. G.") of Berlin. The *P. L. 1*, the first of the L. F. G. airships, was an experimental balloon with a gas-bag 158 feet long and 28 feet in diameter, giving a volume of about 80,000 cubic feet. The cylindrical envevlope, rounded at the front and rear, contained two *ballonets* at either end which by their pressure on the gas maintained the envelope rigid and also served to change the height. In order to rise, the rear one was filled with air, so that the front end was inclined upward and a forward motion through the air tended to raise the balloon, while to descend the reverse process was followed. For considerable changes in height ballast had to be used. The car was hung on trolleys from

two steel cables and moved forward under the impulse of the propeller so that it balanced automatically. The twin screws were driven by a 35-horse-power Mercédès motor, which gave the dirigible a speed of 21 miles an hour. This airship was remodeled in 1909, and finally dismantled in 1911. The later models turned out by the L. F. G. showed a steady improvement in every respect. The last dirigible turned out before the war was the Prussian Army airship *P. V.*, the twenty-second constructed by the company. It was 315 feet long by 51 feet in diameter, the envelope being rounded in front and conical in the rear, with a volume of about 424,000 cubic feet. Three 180-horse-power Maybach engines, turning two pairs of twin screw propellers, drove the airship at a speed of 45 miles an hour. Early in 1915 the Germans attempted to raid Libau with this dirigible, but Russian guns were ready and shot it down.

Another type of dirigible in common use by 1914 was the semi-rigid airship designed by Major Gross and Herr Basenach and usually known as the *Gross* type. Experiments with these machines were begun at the Prussian Army Airship Works in July, 1907. The first

product of this factory was small, having an envelope 134 feet in length by 23 feet in beam, with a volume of 49,500 cubic feet. It was equipped with the special feature peculiar to the *Gross* type: viz., a demountable metal keel hung from the hull. Below this was the car, containing a Körting engine of 25-horse-power driving twin screws. The speed attained was only 18 miles an hour, and the whole dirigible gave little satisfaction. Later models were much more successful, chiefly owing to a great increase in size and power. The last airship of this type of which we have data is the *5a*, which is the Prussian Army airship *M. IV* as it was reconstructed in 1913. In the reconstructed form this dirigible measured 332 feet in length and 44 feet in beam, with a volume of 424,000 cubic feet, exactly that of the *Parseval* type *P. V*. It was equipped with three 150-horse-power Körting engines, giving it a speed of 45 miles per hour. On one occasion this dirigible made the trip from Gotha to Metz in 8 hours and 40 minutes.

The only other German type of dirigible balloon of importance is the Schuette-Lanz. These dirigibles are of the rigid type, like the Zeppelin; but the framework, instead of being

made of aluminum compounds, is constructed of wood stayed by wire, thereby resembling the French *Spiess*. The girders are made of laminated wood, and are spirally wound and held under tension by the stays.

Changes of trim are controlled by the adjustment of lifting planes. The first airship of this type constructed was of huge size, comparable in fact with the *Zeppelins* of that year (1911). The hull, containing the eleven gas-bags, was 430 feet long and 60 feet wide, and was excellently streamlined. The total volume of gas which it contained was about 690,000 cubic feet. Two cars were suspended below this hull, each containing a 270-horse-power Mercédès engine driving a pusher air screw. These 540-horse-power engines gave the giant airship a speed of nearly 45 miles per hour, and they were supplied with fuel sufficient for a flight of 16½ hours. In 1913, while in use by the Prussian Army, this dirigible was caught by a storm while it was moored in the open without protection, and was completely destroyed. The next year, just before the outbreak of the war, a second *Schuette-Lanz* was completed for the Prussian Army. While having the same beam as its predecessor, the

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length and volume were increased to 470 feet and 813,000 cubic feet, respectively. The Mercédès engines were replaced by four 200-horse-power Maybachs mounted in four separate cars and each driving a propeller. Near the bow was a fifth car for the pilot, this one being rigidly connected with the hull instead of suspended below it. The maximum speed of this great fighting machine was about 52 miles an hour, and on one occasion it maintained 42 miles an hour for twenty hours. The best altitude that could be attained was just under 7,000 feet, and this proved to be its weakness for the Russian anti-aircraft guns damaged it so severely in November, 1914, that it was afterward dismantled.

Outside of France and Germany no very notable types of dirigibles were produced up to 1914. In the United States the models developed were mere toys compared with those of Europe. In England the army was compelled to buy abroad and have the foreign designs copied. The best known, because most unusual, of the English aircraft was the Astra Torrés, which had a trefoil section maintained by the gas pressure and internal wire bracing. Italy produced some original designs; notably

the *Forlanini* type which had a rigid girder keel with the car contained in its under part; and the Societá Leonardo da Vinci type (of which the *City of Milan* was a well known example) which had a rigid truss keel ending in a frame to stiffen the bow. Russia, Austria, and Belgium also produced various small airships, but nothing of especial note.

The war has brought rapid changes in dirigibles as in so many other things. New types have developed; old ones have disappeared. Scouting over the battle lines of armies, which was once thought of primary importance, has been reduced by the activity of airplanes and especially of anti-aircraft guns to stealthy trips in the early morning or on overcast days when mists or clouds baffle the watchful eyes of hostile scouts and gunners. Bomb-dropping by night has been made not only ineffectual (no serious military advantage was ever gained by it) but also too costly to be continued. High-powered searchlights and night flying in airplanes combine to render almost certain the loss of a majority of the attacking dirigibles. In one occupation, however, airships have proved of unexpected value. As scouts for the naval forces of both sides they have had

great success in directing offensive and defensive operations. The Germans have used them to direct submarine attacks, as in the case of the Schuette-Lanz type *L.4* which received the Iron Cross for successful co-operation with the submarine *U-9* in the attack which sunk the British cruisers *Aboukir, Cressy,* and *Hogue.* The English and Italians have applied the German method to the meeting of submarine attacks, and it is reported that large numbers of small dirigibles have proved exceedingly valuable as convoys for armed merchantmen, since they are able to give warning of the impending attack. The most notable feat yet accomplished by airships, however, was the part played by the German *Zeppelins* in the Battle of Jutland. These eyes of the fleet brought word that the British battle-cruiser squadron could be surprised far from the supporting fleet and under unfavorable conditions of light. The battle cruisers put up a gallant fight against hopeless odds, trying to hold the German High Seas Fleet until the arrival of the main British forces. The *Zeppelins* brought warning of the impending danger; but in spite of this warning Admiral Beatty's cruisers were partly successful in holding the High Seas

Fig. 25.—Astra-Torrès Coast Patrol Airship.
See page 102.

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Fleet. A partial engagement resulted which lasted until night gave the Kaiser's ships opportunity to escape; but although their losses were heavier than they cared to admit for days afterward (the British assert that the true German losses at Jutland never have been published) the Germans had sunk three splendid British battle-cruisers with all their crews in the opening stages of the conflict.

The types of airships which have accomplished real war service are the same as those in operation before the war, but there has been a diminution in the number of makes. War always causes a survival of the fittest and so it has proved in this case.

In France a rigid censorship has completely suppressed all data as to airships. Whether this silence is because the French dirigibles failed to do what was expected of them and were replaced by airplanes; or whether it is simply part of the general policy of never telling the enemy what he has not already discovered, we do not know. Presumably it is the latter; but it is safe to say that France has relied almost wholly on the airplane throughout the war.

The effect of the war in Germany was to

put an immediate stop to experiments with new models. Only those dirigibles which had proved most valuable could thereafter be built. This instantly eliminated the Parseval and the Gross types, as well as sundry less known makes. The construction of Parseval and of Gross dirigibles was not entirely stopped, but as fast as the circumstances permitted the available factories were turned to other uses according to the reports from Germany. This process of elimination left the rigid type, represented by the *Zeppelins* and the *Schuette-Lanzes,* supreme. The concentration of the best brains of the nation on the problem of improving these two types soon showed its effect.

The *Zeppelins* were already as big as ocean liners when this new development began. The *L-2,* destroyed by fire on its trial trip in the autumn of 1913, was 518 feet, 6 inches long and 52 feet, 6 inches in diameter. Its volume was 953,370 cubic feet and it could lift a total weight of nearly 28 tons. In the two after cars were placed four Maybach motors of 185 horse-power each; these drove four four-bladed propellers by means of gears and shafting. A third car near the bow was reserved for the pilot, and a passageway inside the great

hull connected the three cars. On account of the interior passageway they were hung nearer the hull than was customary with the other models produced by Count von Zeppelin (this fact, as well as the dangerously heavy smoking of the forward engines, is clearly shown in the photograph of the *L-2* leaving for her ill-fated trial trip), and it is believed that this proximity of the motors to the gas-bags was in part responsible for the disaster with which the great airship met. In August, 1914, a sister airship was in operation, and was then by far the largest in service. By March, 1917, the *Zeppelins* were reported as being 787 feet long and 75 feet, 5 inches in greatest diameter. The long familiar shape was changed in these most recent dirigibles, and by using a more nearly streamline form, a speed of 75 miles an hour was attained. Since the death of Count von Zeppelin, it is said that the German government has ceased to build them, but presumably they will still be used as adjuncts to the High Seas Fleet should any further naval engagements take place.

The Schuette-Lanz Luftschiffbau built in 1914 by far the largest dirigible then in existence. This giant of the air, the *L-4*, was 540

feet long, 60 feet in diameter like its predecessors, and 1,060,000 cubic feet in volume. Its speed was 54 miles per hour, attained by the aid of four Mercédès engines having an aggregate horse-power of 1080. It was this *L-4* which co-operated in the sinking of the *Aboukir, Cressy,* and *Hogue,* and which was later wrecked in a storm. The success of this design or the desire for standardization caused this dirigible to become the pattern for all *Schuette-Lanzes* during at least a year. Since that time it is to be assumed that improvements have been made; but the German military authorities are not volunteering information on the subject, and since they have become more cautious in the use of their aircraft the examination of captured dirigibles is less frequently possible.

In England the development of aircraft, both balloons and airplanes had been hampered up to 1914 by the governmental policy of creating as small an air fleet as could satisfy the public demands for safety. What little appreciation there was of the needs of the country was an appreciation of the value of airplanes. With this handicap it was only natural that British designers should have created nothing original

in dirigibles at the outbreak of the great war. The crying need of airplanes and more airplanes during the earlier stages of the conflict caused every energy to be turned into the production of heavier-than-air machines. The rapidly increasing danger from Germany's submarine blockade and the impossibility of building enough submarine chasers at last caused the British government to have large numbers of small dirigibles built. At least the sequence of events leads one to assume that this was the reason for the sudden appearance of the English dirigibles. They were of a new type; not that they were especially unusual, but they were an improvement over anything of their size previously built. They were of the non-rigid type, of small volume, and had as a car the body of an airplane. Their speed obviously was not great; but in fair weather when the submarines were most dangerous these small airships were very effective. The English promptly nicknamed them "blimps," and the name proved so appropriate that it has been generally accepted. The best available description of a blimp is contained in the United States Navy specifications for bids, issued in February, 1917. These specifications describe

the blimp as a "non-rigid self-propelled dirigible for use in connection with coast or harbor patrol." "The envelope fully inflated has a displacement of about 77,000 cubic feet, corresponding to a gross buoyancy of 5,275 pounds when inflated with hydrogen of good commercial purity and under normal conditions of barometer and temperature. The length of the envelope is 160 feet and the maximum diameter 31.5 feet; maximum width over tail fin, 36.2 feet; the center of buoyancy is 69.2 feet from the nose; the height overall is 50 feet; horsepower of motor, 100; maximum safe altitude, 7,500 ft. Designed maximum speed at an altitude of 600 feet, 45 miles per hour; endurance at full speed, 10 hours." Steering and balancing are accomplished with the aid of fins, rudders, and trimming tanks. Kapok floats are provided for alighting on the water.

At the very time when the English are finding small dirigibles an aid to their fleet, and the Germans are reported to have restricted or altogether stopped the building of large dirigibles the Italians are designing and constructing bigger and bigger airships. It is probable that they are not faced by such conditions as pre-

FIG. 26.—A British Submarine Scout Airship.

FIG. 27.—An American "Blimp."

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vail on the western front, where airplanes are in abundance; or else they are building an air fleet to co-operate with their navy. At all events, the dirigibles recently built or now projected by the Societá Leonardo da Vinci are at the other extreme from the English blimps in almost every respect. They are of the semi-rigid type, having a rigid truss girder running from bow to stern as a keel. Attached to this keel is an umbrella-like stiffening which prevents the collapse of the bow at high speeds or with rapid changes of altitude. The most recent Societá Leonardo da Vinci type to be completed is the *F–4*, a photograph of which is shown in Fig. 28. From nose to tail this dirigible measures 293 feet, while its equator diameter is 59 feet. Its gross volume is 530,000 cubic feet, and the gas is placed in twelve separate compartments. The total weight which this gas can lift is 23,540 pounds, of which 20,460 is taken up by the airship itself. When fully equipped for service an altitude of 14,650 feet can be reached, and at that altitude a speed of 47 miles per hour can be maintained. The maximum climbing speed is 640 feet per minute. A new dirigible projected by the Societá Leonardo da Vinci, and to be

called *F–7,* will be 358 feet long, 60 feet in diameter, 1,060,000 cubic feet in volume, and 66 miles per hour in maximum speed; while an altitude of over 21,000 feet will be attainable in it.

The various dirigible balloons described may now be classified into three principal types: the rigid, of which the *Zeppelin* is the most conspicuous example; the semi-rigid, like the *Gross* and the *République;* and the non-rigid, of which the *Parseval* is the best known exponent. The rigid construction has the advantage of strength and durability, but a great weight must be lifted (in the older *Zeppelin* the metallic frame weighed 17,000 pounds) and the airship is not transportable except on the water or in the air under its own power. The cost, also, is great. In the semi-rigid system the gas-bag is pliable but has beneath it a rigid keel which is intended to prevent deformation of the envelope and serves to attach the car. In the non-rigid system (first applied in the *France*) there is no union of cloth and metal, the pliable envelope being entirely independent of the car containing the motors, etc., and connected with it by flexible cords. This type of airships is easily transportable. In all the

maintenance of form is a *sine qua non,* and in balloons other than of the *Zeppelin* type is assured by the *ballonet à air.* The improvement in light motors since 1885 is shown by the fact that, whereas the electric-motor with storage battery used in the *France* weighed 100 pounds per horse-power, present explosive motors weigh as little as three pounds per horse-power, exclusive of fuel; though the average is nearer five pounds per horse-power. While the dirigibility of a balloon depends on the power of its motor, its speed cannot be increased beyond 17 to 25 miles per hour without causing its prow to rise and the balloon to overturn, unless special precautions are taken. Consequently the ratio of the length of the gas bag to its diameter must be carefully adjusted to provide stability of motion, and the bag must be provided with fins at the rear, as far distant as possible from its center of gravity, which, like the feathers on an arrow, tend to control its direction and reduce pitching. Besides stability *en route,* the facility of vertical motion must be afforded by movable planes nearly parallel to the principal axis of the balloon. A dirigible balloon is but little lighter than the air which it displaces, consequently its rise and

fall is effected chiefly by dynamic rather than by static action and without the loss of much ballast or gas. The motive power increases as the cube of the speed for balloons of similar design, and the weight per horse-power diminishes in the same ratio. Taking, for example, a balloon 33 feet in diameter, to give it a velocity of 13½ miles per hour requires the expenditure of 8.64 horse-power, and supposing the motor to absorb one-fifth of the ascensional force, the permissible weight per horse-power is 178 pounds. If we double the speed, that is propel the balloon 27 miles per hour, 69 horse-power will be required, and the weight per horse-power can be but 22 pounds. To gain another 4½ miles per hour requires an addition of 40 horse-power, and 4½ miles more, making the speed 36 miles per hour, would necessitate engines of 163 horse-power, while the weight which can be allowed per horse-power is reduced to 9 pounds. These computations, by Major Paul Renard, show how difficult it is to gain a few miles per hour at high speeds and how rapidly the allowable weight per horse-power decreases. Since the lift of a balloon increases as the cube of its

FIG. 28.— French Anti-Aircraft Gun.

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linear dimensions, but the surface and consequently the resistance of the air, only as the square of these dimensions, it follows that the larger balloon with an equal speed will carry more weight, exclusive of the motors, than the smaller one.

The length of time that a motor-balloon can remain in the air, and therefore its radius of action, are increased by the fact that the lessening lift, due to loss of gas, is offset by the diminishing weight of fuel.

The dirigible balloon has its prototype in Nature in the fish which, though specifically lighter than the medium in which it is immersed, can rise or fall by expanding or contracting its swimming-bladder, represented by the *ballonet* of the aëronaut. Indeed, in the modern balloon the form of the gas-bag resembles the body of a fast-swimming fish.

At the present time dirigible balloons can no longer be considered as useful only on selected days but rather as capable of performing service at almost all times. Thus they can fulfill important functions until they are supplanted by heavier-than-air machines, for it is probable that the conquest of the air will be com-

pleted by apparatus of this type. How man first learned to fly, and the progress which he is making in this new accomplishment, will be described in the next chapter.

# CHAPTER IV

## THE FLYING MACHINE

MAN has always wished to imitate the flight of birds, that he might leave the ground to which he seemed to be confined, and rise freely into the air. After centuries of futile effort the balloon was invented, but even when it had been rendered dirigible it did not satisfy fully the desire which had brought it into being. It was slow and unwieldy; its flight was not at all like the swift and easy passage of birds. Unfortunately scientific investigators proved apparently conclusively that mechanical flight in a heavier-than-air machine of man-carrying size was impossible. This proof, which was based on a fundamental error, was mathematically correct. The wings of a heavier-than-air flying machine are its sole support, and their sustaining power is proportional to their area. For similar structures, however, the weight varies as the volume; and therefore if the size of a wing were doubled the weight

would be quadrupled. At this rate a limit would rapidly be reached beyond which flight would be impossible.

Unfortunately for the theories of learned men, the airplane ultimately was a success; and not until then was it noticed that the assumption as to similar structures was entirely erroneous. Instead of building an airplane like a bird, or even like a small model, it was built on a new pattern which, while in itself subject to the law of area and volume, did not have the same limiting size as the design studied by the scientists. Once this was made clear the study of the laws which governed every phase of flight became a matter not merely of scientific interest but of extreme practical importance. The pioneer constructors of airplanes built largely by experiment or by guess-work, but a permanent industry could not rest on such a flimsy basis.

The first serious investigations carried on in a scientific manner were those begun by Professor Langley in 1880. His results, while they have now been largely supplanted by the work of men favored with far greater facilities for investigation, were the theoretical foundation upon which the experimenters of the next

twenty years built. Dr. Zahm, working in an exceptionally fine laboratory for its time, made exceedingly valuable and permanent discoveries. Meanwhile the Wrights, beginning their work in 1896, tried to continue from the point where the earlier men had ended. They soon found that the empirical results of Langley and of Lillienthal, a practical experimenter, were wrong in quantity, whatever they might be in theory. The Wrights, therefore, conducted their own researches, which ultimately led to the building of a successful airplane.

All these earlier investigations, invaluable as they are, have been completely eclipsed by the scientific study carried on at half a dozen aëronautical laboratories during the last five or six years. Probably the greatest contributions have been made by the National Physical Laboratory, at Teddington, England, in conjunction with the Royal Aircraft Factory at Farnborough; but valuable work has been done by L'Institut Aérotechnique de l'Université de Paris at St. Cyr, France, by M. Gustave Eiffel at his private laboratories, by the Deutsche Versuchsantalt für Luftfahrt at Adlershof, by the Göttingen Aerodynamical Laboratory, by the Massachusetts Institute of Technology, and

by the wind-tunnel of the United States Navy Department at Washington, as well as by investigators in Italy and Russia and scientists in many countries.

The results of the many experiments have given empirical rules, and these have slowly been expanded until their connection with established physical laws has become clear. Only a start has been made in the gigantic task, and every new test opens the way to wider researches; but already the broader, basic facts which must be faced by an aviator or aëronautical engineer are known.

The reason an airplane, or any heavier-than-air machine, flies is because the air strikes its wings at an angle and lifts them up, just as it lifts a kite. It makes no difference whether the air strikes the wings or the wings strike the air so long as there is relative motion between them, and this fact is very important in experiments with models.

The motion of the wings may be a flapping, as in the case of a bird, and this type of flying machine is logically known as an ornithopter. Only small machines have as yet been constructed, and it is probable that they will always remain toys. The secret of bird-flight,

long believed to be an insoluble mystery, is now explained on the supposition that birds are airplanes whose extended wings, apparently stationary, act as sustaining surface, especially near the body, while only the extremities serve to propel the bird. A bird's wing is thus an organ with multiple functions, serving generally as a sustaining plane and propelling force, and occasionally as a sustaining screw. It does not seem probable that man will ever construct ornithopters of large size. As man has abandoned legs and fins for mechanical locomotion on land and water, so in aviation there is no use to imitate beating wings, the movement of rotation being characteristic of machines.

In another type of heavier-than-air flying machine the wings revolve around a central shaft, thus forming a propeller; and from the path theoretically travelled by an ideal propeller, this type is known as a helicopter. It must be remembered that each blade of a propeller is really nothing more than a single wing traveling in a curved path which happens to be a circle with its center at one end of the wing. Thus in the helicopter the support is obtained by screws with vertical axes, and is independ-

ent of the forward motion, which is a considerable advantage. To effect motion in a horizontal direction, another screw is required, or the axis of the supporting screw is inclined to the vertical so that in rising it also advances in a given direction. The helicopter has an advantage over the airplane in requiring only a small space for starting and landing, but is wasteful of motive power because its sustaining power is very much inferior to that of the airplane. This results from the vertical screw setting the mass of air in motion so that its action is not so efficient as when it comes into new masses of air, like those encountered by the airplane propeller.

In the airplanes now used the resistance to their motion forward varies between 1-8 and 1-5 of the weight, requiring the screw to exert that much propulsion. In a helicopter the lifting force must equal the total weight of the apparatus, which must be propelled forward besides. Therefore, while it is improbable that helicopters will ever supplant airplanes, it appears possible to combine the two systems so as to act like a helicopter at the beginning and end of the voyage, in order to facilitate the maneuver in a limited space, and during

the voyage to have the airplane operate in an economical manner.

The third and only successful form of heavier-than-air flying machine is the airplane, and it is to the description of this type that the rest of the chapter will be devoted. The progenitor of the airplane is the glider. This is nothing more than an airplane without a motor. Starting from the edge of a hill, preferably against a light wind, it will slip off on a gentle slope down to the ground below. It was through experiments with man-carrying gliders that the Wrights first learned to fly. Having a successful machine of this type, if we drive it at a little higher speed or start it against a somewhat stronger wind, it will remain at the same level instead of dropping. Since the wind is not to be depended on, the logical thing is to add a motor and propeller to drive the glider; and immediately it becomes an airplane.

Assuming an airplane in steady flight, it is obvious that since the lift of the wings is holding the machine at a given height, it must be exactly equal to the total weight. (The errors introduced by wind-pressure on the body, etc., are negligible except in designing).

Similarly, if the speed of the airplane is constant, the thrust of the propeller must exactly equal the resistance offered by the machine in going through the air at that speed. The forces acting on the airplane being known, it is important to discover how they vary if the speed or the machine is changed. Experiments have established the empirical law that the lift is equal to a constant multiplied by the projected area of the top (or bottom) surfaces of the wings and by the square of the velocity. The constant is different for every wing, and also for every vertical angle between the wing and the path along which the machine is flying. The resistance of an airplane has similarly been shown to be made up of the combined resistances of all the parts; and the resistance of each part varies by the same law as the lift, but always with its own set of constants, and with the projected area taken from in front.

The lift and the resistance being balanced by the weight and the propeller thrust respectively, there still remains the important question of stability and controllability. If the airplane turns from its path due to a gust, it is desirable that it should tend to return automatically to its original attitude; and it would be

useless if it could not be turned voluntarily in any direction at any time. So far as stability is concerned, it is simply a matter of arranging the surfaces of the machine, including the wings, the body, and the tail if there is one, in such a manner that if the airplane, when in steady flight, tips in any direction a force is at once created tending to bring it back to its original attitude and leave it there in equilibrium. This delicate adjustment is not easy to attain, and in part must be secured in each case by the aid of tests on models, since scientific theory is unable to solve some of the problems it involves. Controllability, on the other hand, is easy to secure by means of rudders, ailerons, etc. Movements up and down can be controlled within certain limits wholly by the speed of the motor. Thus if the airplane is in steady horizontal flight and the motor is speeded up, the horizontal speed will remain the same, but the machine will rise; and conversely if the motor were shut off, the airplane would glide down to earth. Greater changes in the vertical plane are effected (in the ordinary type of airplane) by means of the horizontal rudder on the tail, which is known as the elevator. Steering to right and left is

done with the vertical rudder, or simply that part of the tail known as the rudder. Lateral balancing is accomplished by warping the wings or by turning the ailerons, which are flaps attached to struts or to the rear edge of the wings near the tips. In the special case of the Dunne-type airplane, which has no tail, the ailerons act not only in their usual capacity but also as rudder and elevator.

The wings themselves in an airplane vary in infinite ways. It was discovered at once in the early days of glider flying that a flat plane is very inefficient as a wing. The question was to find what shape was the best. All kinds were tried and are still being tried, but no law governing the variation of efficiency with changes of shape has been established. Approximate rules are known, but the effect of a radical change cannot be predicted. Experience has shown that the best type of wing is one having a fore-and-aft section with a marked curvature of the upper surface, but with only slight curvature of the lower side. The greater part of the lift obtained from this (or in fact any other) type of wing is caused by the suction on the upper surface; while the

positive pressure on the under side plays only a minor part.

There are three familiar arrangements of the wings on airplanes. In the first place, there is the possibility of having a single wing on each side of the body. A machine of this type is known as a monoplane, and while it is little used now, it has an important place in the history of aviation since 1908. The second and now almost universal type is the biplane, which has two sets of supporting surfaces, one over the other. Although the superposing of surfaces diminishes the lift obtained from each unit area, and so diminishes the efficiency of the wings, a much lighter construction for the same strength is obtained by the truss bracing thereby rendered possible. These considerations balance one another to a large extent, and when the need is felt for more surface than can conveniently be put into a single pair of wings, the biplane becomes the logical form. The third familiar arrangement of surfaces is the triplane. The same reasons which lead to the use of the biplane instead of the monoplane also tend to make the triplane logical for extremely large machines. Oddly enough both

the triplane and, to a less extent, the biplane are more efficient than the monoplane, when their wings make large or very small angles with the wind. As the large angles correspond to a large lift at relatively low speeds and the small angles give small lift except at extremely high speeds, it follows that for very large but slow machines or for very fast machines the triplane would appear to be superior to the biplane and both to the monoplane. It seems probable, therefore, that for huge weight-carrying airplanes or trans-oceanic liners of the air and also for racers and military "pursuit" machines the triplane will soon be the customary type. Doubtless the development will go further and we shall eventually see multiplanes with [illegible] more superposed sets of wings.

There is indeed, no reason why various unusual forms of airplane should not be built except that for the present at least they are less efficient than existing types. Successful multiplanes have already been built and as soon as the need is felt for a model more radical than the triplane they will undoubtedly be built [illegible] double monoplanes and [illegible] have also been built at various times in the past. Professor Langley built a

double monoplane as early as 1903, and a photograph of it is shown in Fig. 32. These double monoplanes and biplanes are very stable, but they are clumsy, and stability can be obtained in other ways. It seems improbable that we shall see their kind again unless even the multiplanes fail to provide enough lifting surface for some giant weight-carrier of the future; and such a situation is unlikely for a long time to come.

Even after men had learned to fly it was some time before the secret of starting from the water was discovered. Light, rubber-tired wheels rolling across smooth ground make almost no resistance; but to push a large float through the water until it rises and skims the surface, or planes, as it is called, is a difficult task. When the solution of the difficulty was finally arrived at, two forms were developed. In one the wheels of the ordinary land airplane are replaced by one or two floats, usually with small additional floats under the wing tips and tail to prevent the machine from tipping wholly over if it should tilt in any direction. In the other type the body is hung below the wings and is in the shape of a boat with a long, narrow stern curving up into a tail. A modifica-

tion of this latter type has a simple boat body and the tail of the airplane attached to the wings by long spars. None of these forms is as efficient aërodynamically as the corresponding land machines, for both the weight and the resistance of the floats or boat body are great.

We have now considered the fundamental facts at the basis of mechanical flight and the broader divisions into which the airplane as a type may be separated. Many other classifications are possible, and perhaps some of them would, on careful analysis, prove to be more logical; but there seems to be none so distinctive and at the same time so simple and obvious at a glance. The subtler, or rather less important, variations of type are almost innumerable, and a majority of the more noticeable ones can probably be treated better when we consider individual makes of airplanes in the next chapter. Certain characteristics, however, lend themselves to an interesting comparison with the corresponding characteristics of the dirigible balloon.

In the first place, there is a strong contrast in size. The latest *Zeppelins* are 787 feet long and 75 feet, 5 inches in diameter. Just what

FIG. 29.—A French "Parasol" Monoplane.

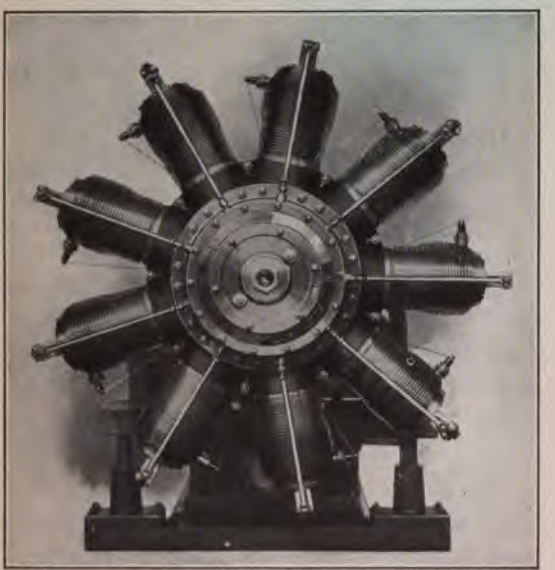

FIG. 30.—A 100 H.P. Gnome Rotary Engine.
See page 133.

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the largest airplane is we do not know, but there are a number of machines in use which are about a hundred feet in span (from wing tip to wing tip) and probably about fifty or sixty feet in length. Experiments were carried out by one American company with a view to building a triplane of 133-foot span, but the project was afterward dropped when the British government decided that smaller machines would serve as well. With the data for this machine as a basis, we can, however, form a good comparison with the *Zeppelins*. Long ago a *Zeppelin* lifted 28 tons into the air, whereas this great triplane, although only one-fifth the size of the airship, was intended to lift over 10 tons. The speed of the dirigible was only about 55 miles per hour, while the airplane was designed to reach 75 or even perhaps 100 miles an hour; but it should be remarked that the *Zeppelin* had engines of only 540 horse-power, instead of the 1060 horse-power developed by the motors of the triplane. The latter machine's radius of action of 750 miles was unquestionably exceeded by that of the airship.

At the other end of the scale in size the contrast is even more striking. The smallest

modern dirigibles are the blimps, and the smallest airplanes are the military pursuit machines. The blimp, as designed for the American navy, is 160 feet long and 31.5 feet in diameter, and makes a speed of 45 miles per hour for ten hours. A typical pursuit type airplane is about 25 feet in span by 18 feet in length, with a motor of 100 to 150 horse-power and a speed of 125 miles per hour. The endurance at this maximum speed is 2½ to 3 hours.

The facts which are most striking in this contrast of types are that the present day airplanes are much smaller than any dirigible, and also much faster, but that in endurance they are inferior. It is also interesting to note that while it is the largest dirigible which has the greatest speed, in the case of the airplane, the reverse is true. This is due to the fact that the gas of a dirigible gives a definite lift irrespective of speed, but the wings of an airplane lift, at a given angle, in direct proportion to the speed. Whether heavier-than-air machines will ever equal airships in lifting power depends, to a great extent, on our ability continually to improve on structural methods so as to postpone indefinitely the long-threatened limiting size.

Although airplanes already attain tremendous speeds, there is always the endeavor to go still faster. At first glance it would seem as though a mere increase of horse-power would be sufficient to gain extra speed. Unfortunately the puzzle is not solved so easily. Increased horse-power means a heavier motor, and that in turn entails a larger and heavier wing structure. A larger and heavier machine, however, needs more power to drive it at the speed with which we started; and only the surplus power, if there is any, is left for increasing the speed. The designer, under these circumstances, is traveling in a circle; and sooner or later the time comes when it is no longer profitable to increase the horse-power: the surplus power has all been eaten up in driving itself and leaves nothing additional for the machine.

The remedy for this difficulty is a lighter motor or a lighter structure in the machine. Lighter motors are constantly being produced, but the necessity for reliability makes progress in this direction rather slow. Lighter or more efficient structures are not easy to obtain. In Europe the demand for speed has led to reduction in the factor of safety. Ordinary struc-

tures, like bridges and most airplanes, are built to withstand a strain not less than eight times the largest which they would ordinarily be called upon to bear. This factor of safety, as it is called, is intended to prevent a collapse under exceptional circumstances or in case of faulty material. In European pursuit machines this factor has been cut down to two or three, without regard for the imminent danger of collapse in the air. It is said that as a result of such methods certain German machines have recently seemed to disintegrate the instant they were hit by a bullet. The wings, body, and tail have fallen apart and come down widely separated from each other.

In spite of the fact that European designers have been forced to such desperate methods to gain speed, there is no reason to believe that an absolute limit has been reached. Better body forms will lower resistance in the future; new structural methods will reduce weight; new wing curves will have less drag; and new engines will weigh less per horse-power developed.

One of the most promising opportunities for improvement lies in the engines. It is a far cry from the motor of Captain Renard, built in

1885, which "had the unprecedented lightness of 100 pounds per horse-power," to the new Hispano-Suiza, weighing a little more than 3½ pounds per horse-power complete; but the end is not yet in sight. The coming of the gasoline engine immediately reduced the weight enormously. In fact an engine was built as early as 1901 which weighed only 3.65 pounds per horse-power, but it was not a commercial type. When the airplane had become a proved success, there was a prompt attempt to cut down the weight of engines which could be put on the market commercially. Ultimately a type was designed which lowered the weight to 2.2 pounds per horse-power, but this record was achieved at the expense of reliability. A reaction from this excessive lightness led to motors weighing 5 and 6 pounds per horse-power, but now there is a steady decrease in the weight of reliable engines.

Aviation has developed its own forms of engines to a certain extent. The earliest ones were chiefly of the automobile variety; but almost at once the Gnome rotary type was invented. This form of motor has the cylinders revolve around a stationary shaft in the center instead of having stationary cylinders and a re-

volving crank-shaft. The great gain by using revolving cylinders lies in the possibility of cooling by air instead of water. If the motor were not cooled it would become red hot; but a motor with cylinders arranged star-wise around a central hub and revolving a thousand times a minute keeps sufficiently cool without the aid of water, which adds to the weight. Fig. 30 gives an excellent idea of how a motor of this type looks. The cylinders have a series of narrow fins extending clear round them to aid in the cooling. A somewhat similar type of motor has the cylinders arranged in the same way, but fixed in place and water cooled.

Another development in motors, which has earned a permanent place for itself in the industry, is the V-type engine. This variety has two sets of cylinders arranged at an angle to each other along a single crank-shaft. Each set corresponds to the old type automobile engine. The motors of this form are built with eight, twelve, or more cylinders; although the engines with more than twelve are so unusual as to be termed experiments, and are probably not in use at present. The success of the V motor for airplanes led to its adoption for automobiles, and it is now one of the most popular

kinds in use. The outstanding advantage of this sort of engine is the ease of constructing it in powers higher than could be comfortably put into any other form. Single units of 300 horse-power are common, and some of 600 horse-power have been built in this shape.

The position of a motor in an airplane has a tendency to affect its design. In the early days of aviation, the commonest variety of airplane was the pusher biplane, where the propeller was at the rear of a short body and turned inside of the outriggers which held the tail. Stream-lining was unheard of in those days and any shape of motor was good enough. The monoplanes, with the power plant in front driving a tractor screw, were as little stream-lined as the biplanes in many instances, although there were one or two notable exceptions. Under these conditions the rotary motor flourished, partly because no one cared about resistance, chiefly because of its undoubted good qualities.

Gradually the tractor (with the propeller in front) became the customary type and the demand for speed led to more and more efficient stream-lining; but wherever the rotary motor was used there was trouble. To cover the en-

gine in made it over-heat, and not to cover it in ruined the speed. Compromises were tried, and for a long time a partial covering was used. The advent of very efficient water-cooled engines with great economy of gasoline consumption, coming at the same time as the demand for higher powered units than were convenient in the rotary type, and for endurance so great as to make their more economical gasoline consumption nullify their original disadvantage of weight, has restricted the field of usefulness of the rotary motor. It is no longer the most reliable type, and except for short flights it is not the lightest. It is reported that even the pursuit machines have had to finally abandon it in favor of the Hispano-Suiza, and similar motors.

In Germany and Austria the six-cylinder, vertical, water-cooled motor of the automobile type has long been the standard form. It must be admitted that the vertical type lends itself to easy stream-lining, but when the horsepower of single units rises above 150, it becomes a little more difficult to put it in six cylinders. Moreover, attempts are being made to produce a V-type engine with only a narrow angle between the sides of the V, and such a type is

almost as easily stream-lined as the vertical motor.

To sum up the present situation in aviation, we may safely say that progress is being made toward higher powered engines for all airplanes, toward larger airplanes for weight-carrying, and toward faster airplanes for all but the school types. Automatic stability is now possible without elaborate mechanical devices, and it will soon be universal. Airplane engines are rapidly increasing in power and reliability, and in the bigger units at least, are usually of the V-type, water-cooled. The airplanes which we now have are no longer either experiments or the crude products of a new industry. They are far from perfection, to be sure, but they are, and must be classed, as efficient mechanisms serving with reliability those purposes for which they are designed. The elements have ceased to dominate the conditions of flight; they modify them, but no longer control. Where necessity compels, man can fly at will in any weather conditions short of a hurricane; that achievement marks the conquest of the air.

# CHAPTER V

## THE HISTORY OF AVIATION

MOST of the inventions which we make use of to-day, such as railroads, steamboats, telegraphy, and photography, are of recent date and were not thought of 200 years ago. The secret of aviation, however, has defied all efforts for a much longer period, because man has not merely dreamed of the conquest of the air but also attempted to realize it with inadequate motors. The partial solution of the problem of flight by aëro-station did not stop the pursuit of aviation, and since the end of the eighteenth century patient investigators everywhere have been seeking to achieve dynamic locomotion in the air. Failures were many, but in our own day has come the end of the long search.

Let us examine the more important attempts which have led to the accomplishment of mechanical flight. In the first place, we can point with pride to the fact that, whereas the balloon

is certainly of French origin, the problem of human flight, by a machine heavier than air, was solved in America, and the names of Langley, Chanute, and Wright will always be honored as having successfully promoted the navigation of the air by machines heavier than itself.

In considering the lines of investigation, we may divide them into two categories; first, the trials of models, or full-sized machines provided with motors, and second, the experiments with soaring or gliding surfaces to which motor power was applied only after stability was obtained. While this last and more recent method is the one which led to the modern airplane, we will first consider the earlier experiments made with motor-machines, which culminated in the successful but unappreciated double monoplane designed by Langley.

The first airplane which had any chance of success was designed by Henson, in England, in 1843. This so-called "aërial steam carriage," which does not appear to have been constructed, had wings that measured 140 feet across, and although the proposed steam engine which drove the propellers weighed too much to permit the apparatus to leave the ground,

yet Henson's project may be regarded as the precursor of the flying-machine of to-day.

During the latter half of the nineteenth century many experiments with power flying-models, driven by twisted rubber, compressed air and steam, were made by Pénaud, Tatin, Hargrave, Phillips, Langley, and Richet. The most successful experiment was that of the late Professor Langley, secretary of the Smithsonian Institution, whose *Aërodrome,* weighing 27 pounds, and driven by a one-horse-power steam engine, in 1896 made three flights of about three-fourths of a mile each, over the Potomac River, near Washington, the apparatus alighting safely each time, and being in condition to be flown again. This, the first flying-machine to be propelled a long distance by its own power, is shown in flight in Fig. 31. Quoting from Mr. Chanute, the eminent engineer of Chicago, whose own experiments and writings have been of the greatest service to aviation, the striking fact which appears from all these model experiments is, that it requires a relatively enormous power to obtain support in the air. Taking the best data, the weights sustained were but 30 to 35 pounds to the horse-power expended, thus comparing

FIG. 31.—Langley *Aërodrome* in Flight.

FIG. 32.—Langley's *Aërodrome* as Flown in 1914.
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most unfavorably with the weights transported by land or by water; for a locomotive can haul about 4,000 pounds to the horse-power upon a level track, and a steamer can propel a displacement of 4,000 pounds per horse-power on the water at a speed of 14 miles per hour.

Professor Langley, in his epoch-making work, *Experiments in Aërodynamics,* published in 1891, made this prediction: "The mechanical suspension of heavy bodies in the air, combined with very great speeds, is not only possible, but within reach of mechanical means which we actually possess." After the successful flight of his model in 1896, Professor Langley wrote: "I have brought to a close the portion of the work which seemed to be especially mine — the demonstration of the practicability of mechanical flight, and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it does not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened."

After experimenting with models which are

often unsuitable for reproduction on a large scale, four famous inventors, Maxim, Ader, Kress, and Langley, each constructed a machine to carry a man, and all were unsuccessful because they lacked stability and strength. In 1894, Sir Hiram Maxim built in England a flying-machine to carry three men, which has never been equaled in size. It was a multiplane of 104 foot span and 4,000 square feet surface; and was driven, through two 17-foot 10-inch propellers, by a 360 horse-power steam engine of novel design with the remarkable lightness of 11 pounds per horse-power. The machine ran on a track and was prevented from rising far by a rail above. At a speed of 36 miles per hour all the weight of 8,000 pounds was sustained in the air, but in the final test the machine, which is said to have cost $100,000, left the track, and was wrecked.

In 1897, C. E. Ader, a French mechanical engineer, with a grant of $100,000 from the French War Department built his third machine (to which he gave the name of *Avion*), whose form was that of a great bird, with 270 square feet of surface and a weight of 1,100 pounds. Twin screws were turned by a 40-horse-power steam engine which weighed

only 7 pounds per horse-power. This machine is said to have flown more than 500 feet in a test at Sartory before a military commission, but its defective balance causing an accident, further aid was refused, and the machine was abandoned.

In 1901, W. Kress of Vienna tested an apparatus with tandem surfaces of 1,011 square feet, the model of which gave good results, but which failed with an inadequate motor.

After the successful flight of the *Aërodrome* Professor Langley obtained a grant of $50,000 from the United States War Department to construct a flying-machine capable of carrying a man. The machine was essentially an enlargement of the model, and with C. M. Manly on board it was twice launched from a house-boat on the Potomac in 1903. In both cases, however, the apparatus, caught in the launching-ways, was precipitated into the river, and Professor Langley, discouraged by the ridicule of the press and deprived of additional funds, abandoned further experiments. The machine which met with these unfortunate accidents had a supporting surface of 1,040 square feet and a weight of only 850 pounds. It was driven by a fixed star, or radial, water-

cooled gasoline engine which developed 52.4 horse-power, yet only weighed 207 pounds complete. This astounding motor, which has only recently been equalled in weight per horse-power by a water-cooled engine, was constructed by Charles M. Manly, Professor Langley's assistant. In 1914, Glenn H. Curtiss repaired this airplane; and after adding floats weighing 340 pounds (a heavy over-load for such a machine) flew it with ease over the waters of Lake Keuka, New York. Fig. 32 shows it as it appeared at that time. The failure of Samuel P. Langley to receive during his lifetime the honors due him from the scientists, the government, and the public, as the first man to construct a successful airplane, is one of the tragedies of the history of science. His assistant, Charles M. Manly, has fortunately lived to see the researches of Professor Langley justified and honored, and his own achievements properly appreciated.

With the abandonment of "Langley's Folly," as it was called, in 1903, the attempt to produce a successful airplane by experimenting with models and full-sized motored machines, ended. Another school of thought had been working on the same problem, and

FIG. 33.— Lilienthal Glider Descending.

FIG. 34.— Wright Glider Descending.
See page 147.

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its labor was about to bear fruit by winning that public recognition which Langley so narrowly missed.

Otto Lilienthal, a German engineer, built, between 1891 and 1896 a number of flying machines, with which, using gravity as a motive power and starting from a hill-top he practised gliding flight, and thus traversed a distance of 400 yards through the air. His last glider with superposed surfaces is shown in Fig. 33. Lilienthal also proposed to apply a motor to his glider, but after making more than 2,000 flights he was killed in 1896 by the machine upsetting in a gust of wind, and three years later the same fate befell Mr. Pilcher, an English engineer, who was using a modified glider. Both these operators shifted their weight so that the center of gravity fell on the same vertical line as the center of pressure, which oscillated through changes in the wind.

Lilienthal had no imitators in Germany, but, in 1896, Octave Chanute in America began to experiment with man-carrying gliding-machines, in which he reversed the method of Lilienthal to restore balance and caused the surfaces themselves to alter their position, so

as to bring the center of pressure back vertically over the center of gravity. Several forms were tried, including a multiple-wing machine, with which the angle of descent was about 10 degrees to the horizon. In this, five pairs of wings were pivoted upon each side of a truss permitting them to be pushed back or drawn forward as the wind increased or decreased. Another glider had two superposed surfaces and a tail or rudder for equilibrium. This gave an angle of descent as small as 8 degrees, with a velocity of 17 miles an hour, and nearly 1,000 glides were made without accident to the operator. Messrs. Herring and Avery collaborated with Mr. Chanute in these experiments.

In 1900 Wilbur and Orville Wright, bicycle-makers of Dayton, Ohio, got into communication with Chanute and undertook experiments based on a radically different principle. Instead of automatic equilibrium, obtained by surfaces making a dihedral angle with one another, the machine was arranged so that it would not tend to right itself but be as inert as possible to the effects of change of direction or speed, in order to reduce the effect of gusts of wind to a minimum. The fore-and-

aft stability was secured by giving the airplane a peculiar shape and the lateral balance by arching the surface from tip to tip, or just the reverse of what had been done by some preceding experiments. Thus by contrivances actuated by the operator the balance could be regulated. Practically this was done by an adjustable rudder in front and warping the tips of the wings. The operator lay horizontally to diminish the resistance of his body, and in landing a pair of runners slid on the ground and checked the momentum.

A thousand glides were made from a sandy hill on the North Carolina coast during the next three years, without accident, the airplane sometimes hovering in the air for a minute or more, and covering distances up to 600 feet, the angle of descent having been reduced to 5 or 6 degrees (Fig. 34). As a relative wind of about 20 miles an hour was necessary to support the glider the experiments were generally made with a wind of from 9 to 28 miles per hour, blowing up the hill.

The Wrights were now in a position to build a successful power-flyer and accordingly they applied to the glider a 16-horse-power motor driving double screws behind, bringing

the total weight of the apparatus up to 750 pounds. A view of this airplane is shown in Fig. 35; it gives an excellent idea of the arch of the wings (afterward abandoned as undesirable) and the position of the motor and propellers, as well as the arrangement of the chain drive to the sprockets on the propeller shafts. The elevator (in front of the airplane) may be dimly seen behind the right hand propeller and the neighboring struts. On December 17, 1903, it was tried on the Kill-Devil dunes, North Carolina, against a wind of 22 miles an hour. After running on a rail for a distance of 40 feet the machine rose into the air to a height of 10 feet, advanced with an actual speed of 10 miles an hour over the ground, and 30 or 35 miles through the air. The first trial lasted only twelve seconds, but succeeding trials increased in length until in the last the machine remained in the air fifty-nine seconds, and covered a distance of 852 feet. These, then, were the first considerable flights in a motor-driven flying machine carrying a man. The experiments were transferred to a field in the environs of Dayton in the spring of 1904, but it was not until the autumn that flights were made in a circle. Finally on Oc-

FIG. 35.—The First Wright Airplane.

FIG. 36.—*June Bug* in Flight.
See page 155.

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tober 5, 1905, a distance of 24 miles was traversed in thirty-eight minutes.

At this time the Wrights, failing to interest the United States government, offered through Captain Ferber of Paris to sell to the French the machine, guaranteed to fly 30 miles an hour, for the sum of $200,000. Although the experiments of the Wrights had been reported in France, their claims were not generally believed, and the offer to sell the machine was not accepted. Public interest, however, was aroused. Captain Ferber had already experimented with a glider of the Chanute type, and had studied the question of applying a motor. Mr. Archdeacon had done the same with airplanes dragged over the water, but the first aviator who rose by self-contained power, before a board of control, was A. Santos-Dumont. He used a cellular airplane, resembling a Hargrave kite, with a box-like rudder in front, and driven by an aluminum screw connected to a 40–50 horse-power explosive engine. As there was no tail in the rear of the wings, this machine had the appearance of a flying duck, with the neck stretched out in front. Two bicycle wheels allowed the airplane to run on the ground until the velocity

was sufficient to raise it by the action of the air under the wings. On September 13, 1906, Santos-Dumont rose from the ground with a velocity of 23 miles an hour, and progressed 30 feet through the air, thereby proving to those persons who ignored the flights of Ader and the Wrights, that mechanical flight was possible. On November 12, 1906, Santos-Dumont made a flight of more than 700 feet and won several prizes offered by the French Aëro-Club.

Other French experimenters, such as Esnault-Pelterie, Blériot and de La Vaulx, tried monoplanes during the next two years, with more or less success, but Farman and Delagrange achieved the most brilliant results with biplanes constructed by Voisin brothers, specialists in aviation apparatus. Delagrange, a French sculptor, first demonstrated the biplane in Europe on March 30, 1907. Farman, who on October 26, 1907, attained a distance of half a mile in a straight line, was soon able to describe circles, and on February 11, 1908, made the first complete circuit of about a mile in one minute and a half. In the summer of 1908 Farman came to America and exhibited his machine in New York. Returning to

France he carried a passenger a distance of three-quarters of a mile, and on October 30 made the first journey by airplane, from place to place, namely from Chalons to Rheims, a distance of 17 miles, and in so doing was obliged to rise about 200 feet to clear some tall poplars. Delagrange became enthusiastic over the possibilities of the airplane and after making some records in France exhibited the Voisin machine in Italy. At Milan, on June 22, 1908, he made a flight of 10½ miles in sixteen minutes, the longest flight which had yet been made in public. The success of the dirigible balloon abroad, and the advent of aviation in France caused the Chief Signal Officer of the United States Army, in December, 1907, to invite bids for a dirigible balloon and for a heavier-than-air flying-machine, with a view to develop practical aviation in this country, and to supply the War Department with machines for military service. The specifications for the latter required the machine to carry one passenger besides the aviator, to remain in the air on an endurance test for a period of one hour without landing, and be subjected to a speed test over a measured course of more than five miles, against and with the wind, attaining

a maximum speed of 36 miles per hour. The machine was to carry fuel for a continuous flight of not less than 125 miles. At that time the conditions were regarded as severe, and beyond what had been accomplished. Nevertheless, bids were received from the Wright brothers to furnish a machine having a speed of 40 miles for the sum of $25,000, and from A. M. Herring of New York for one costing $20,000. The Wrights, having constructed a motor-flyer, proceeded to try it on the North Carolina coast, the place of their former experiments, in May, 1908. The trials were witnessed by newspaper correspondents, and one flight of five miles was made in seven and one-half minutes.

About the same time a French syndicate purchased the Wright patents in France, for the sum of $100,000, conditional on two flights of 31 miles in one hour each, carrying a passenger and sufficient fuel for a voyage of 125 miles, and Wilbur Wright, the elder of the brothers, went to France to make these demonstrations, the race course near Le Mans being chosen as the place for the experiments. The first flight was made August 8, 1908, in the presence of many French aviators, and

flights were continued until the end of the year at the Camp of Auvours, during which Wilbur Wright not only fulfilled the conditions imposed by the syndicate, but also won several aviation prizes, and beat the French records for duration, distance, and height of flights. Then on September 21, 42 miles were accomplished in one hour and thirty-one minutes, and on October 10 a flight of more than an hour was made with a passenger. Many passengers, including ladies, were taken up. On one occasion the height of 380 feet was reached and finally, on the last day of the year, all records for distance and duration were broken by a flight of 77 miles in two hours and twenty minutes.

Meanwhile Orville Wright had begun at Fort Myer, near Washington, the tests required by the War Department, and had made some flights of more than an hour. He had also carried separately two officers of the Signal Corps and on September 17 had as passenger Lieutenant Selfridge. When the machine was at an altitude of about 100 feet, one screw caught in a wire connecting the rudder and broke. The equilibrium was disturbed and the machine fell to the ground with violence,

killing Lieutenant Selfridge and seriously injuring Mr. Wright. This accident put an end to the trials, but the Government, satisfied that the machine could fulfill the conditions imposed, extended the time limit to the following year.

The appearance and construction of the Wright biplane are evident from the frontispiece, which shows it in a flight at Fort Myer, on September 9, 1908. A remarkable fact about the Wright machine was that it had undergone practically no change of construction since it was first designed in 1903, showing the care with which all the details were studied.

It had a biplane cell with a spread of 40 feet and a width, or chord, of six and one-half feet from front to rear; the gap, or distance between the two surfaces, being six feet. The area of supporting surface was about 500 square feet and the weight about 800 pounds. The lateral balance was secured by warping the tips of the wings, a feature originated by Le Bris in 1867. This construction has since been abandoned in favor of ailerons and a rigid biplane truss. The motor, designed by the Wrights, was of the vertical, four cylinder,

water-cooled type, and developed about 25 horse-power.

Before the Wright biplane had passed its government tests, another American airplane had made its appearance. This was the *June Bug,* built by the Aërial Experiment Association according to the design of Glenn H. Curtiss. The Aërial Experiment Association, founded and supported by Dr. Alexander Graham Bell, was an organization of five men interested in the problem of flight, each of whom was to build a machine. Curtiss, avoiding the errors of those members who went before him, produced the first successful one. It was a biplane, with the wings converging toward the tips, as shown in Fig. 36. Its weight of 650 pounds was carried by 370 square feet of wing surface. With this flyer, G. H. Curtiss won the *Scientific American* trophy on July 4, 1908, traveling more than a mile at Hammondsport, New York, at a speed of about 39 miles an hour, when the photograph reproduced above was taken. A later flyer, the *Silver Dart,* designed by J. A. D. McCurdy, circled over the ice in Baddeck Bay, Nova Scotia, nearly six miles in about eight minutes.

It may be said that both the Curtiss and the Voisin flyers were evolved independently from the Lillienthal-Chanute gliders, to which the Wrights were the first to apply a motor. Chanute, it should be mentioned, was familiar with the experiments of Langley, and probably used some of the knowledge thus gained. Dr. Alexander Graham Bell was also in possession of the results of Langley's researches, but how much effect this had on Curtiss's *June Bug* is uncertain. The early French monoplanes, however, were the direct outcome of the Langley-Ader experiments.

The first of these latter machines to achieve fame was the Blériot. M. Blériot began his experiments by copying Langley's double monoplane very closely. His success was slight compared with that of the Wrights; but he persevered, gradually reducing the rear plane until it became a mere tail. His great need, however, was financial backing; and at last, in the hope of obtaining publicity, he essayed the desperate experiment of crossing the English Channel in an airplane unprovided with floats or other buoying devices to keep it afloat in case of engine failure. Fortune was with him, and with the Channel crossing to his

credit his position in the aëronautic world was thereafter secure.

Once mechanical flight had been demonstrated publicly, designers sprang up everywhere. Large prizes were offered in every country for every kind of record, and exhibition flying brought rich rewards. Men with no idea of the principles of aviation tried to build airplanes of every sort, possible and impossible. Most of the construction was by cut-and-try methods, and it was inevitable that the loss of life in this early period should be heavy. Gradually the types became somewhat standardized as men realized just what the limitations of this new form of locomotion were. Successful airplanes began to be turned out almost solely by firms with proper facilities for building. Hundreds of home-made machines flew, but few of them did much more.

The characteristic feature of this period in the history of aviation was the breaking of records. There was a continual and successful striving to better the existing marks in speed, altitude, duration, and distance. Aviation meets were frequent, and it was seldom that one passed without establishing a new world's record. A list of the world's altitude

records from 1908 to 1914 will show better than words the rivalry which existed.

| | *Date* | | *Pilot* | *Altitude* |
|---|---|---|---|---|
| 1908 | Nov. | 13 | H. Farman | 82 feet |
| | Nov. | 13 | W. Wright | 82 feet |
| | Dec. | 18 | W. Wright | 328 feet |
| 1909 | July | 18 | Paulhan | 492 feet |
| | Aug. | 29 | Latham | 509 feet |
| | Sept. | 30 | Rougier | 633 feet |
| | Oct. | 18 | de Lambert | 984 feet |
| | Dec. | 1 | Latham | 1,161 feet |
| 1910 | Jan. | 7 | Latham | 3,281 feet |
| | Jan. | 12 | Paulhan | 4,163 feet |
| | June | 14 | Brookins | 4,380 feet |
| | July | 7 | Latham | 4,541 feet |
| | July | 7 | Olieslagers | 5,643 feet |
| | July | 10 | Brookins | 6,234 feet |
| | Aug. | 11 | Drexel | 6,604 feet |
| | Aug. | 29 | Morane | 7,054 feet |
| | Sept. | 3 | Morane | 8,471 feet |
| | Sept. | 8 | Chavez | 8,488 feet |
| | Oct. | 1 | Wyjnmalen | 9,121 feet |
| | Oct. | 15 | Drexel | 9,449 feet |
| | Oct. | 31 | Johnstone | 9,711 feet |
| | Dec. | 9 | Legagneux | 10,171 feet |
| 1911 | July | 9 | Loridan | 10,499 feet |
| | Aug. | 5 | Félix | 10,991 feet |
| | Aug. | | Beachy | 11,578 feet |
| | Sept. | 4 | Garros | 12,959 feet |
| 1912 | June | | Blaschke | 14,300 feet |
| | Sept. | 6 | Garros | 16,273 feet |
| | Sept. | 17 | Legagneux | 17,881 feet |
| | Dec. | 11 | Garros | 18,373 feet |
| 1913 | Mar. | 11 | Perreyon | 19,291 feet |

| | *Date* | *Pilot* | *Altitude* |
|---|---|---|---|
| | Dec. 27 | Legagneux | 19,900 feet |
| 1914 | July 9 | Linnekögel | 21,125 feet |
| | July 14 | Oelerich | 26,568 feet |

As early as 1909 the Gordon Bennett Cup was offered as an international speed prize. The first race was held at Rheims, France, in August of that year, and was won by Glenn H. Curtiss, flying a little biplane of his own make which attained the then excellent speed of 43 miles per hour. Since the United States had won the cup, the race of 1910 was held on Long Island; but the defending team was unsuccessful, and the English won the race. In 1911 the United States, in the person of Charles Terres Weymann, recaptured the trophy; but the elation at the victory was somewhat tempered by the fact that the winner had flown a French airplane. The next year the French made a serious effort to lift the cup, and they were so successful that the race was a mere farce. Jules Védrines, flying a 160 horse-power Deperdussin monoplane, increased Weymann's record of 80 miles per hour made on a Nieuport monoplane the year before, to 105 miles per hour. In 1913, the French mastery in speed was practically undisputed, for

the only foreign entrant, a Belgian flying a French machine, was defeated by all three members of the French team. The winner, Prévost, flew a 200 horse-power Deperdussin monoplane at a speed of 126.59 miles per hour. The race in 1914 was never held, owing to the war: but the rules of competition had been changed, requiring a slow speed test as well as a race for maximum speed, and it is probable that under these rules one of the little English biplanes would have won the event as easily as the Sopwith won the Schneider Cup for speed in airplanes with floats or boat bodies.

There were so many things which had never been done, but only awaited the doing, that as soon as reliable (or even somewhat reliable) motors were available, aviators appeared everywhere, making trips from this city to that or crossing some lake, or strait, or mountain range. In 1911 the trip from London to Paris was made by Prier, 290 miles without a stop. In the same year Harry Atwood flew from St. Louis to New York by easy stages, the first time a long cross-country flight had been made in the United States. The year before, 1910, the Peruvian aviator, Chavez, crossed the Alps from Switzerland to Italy; but in landing he

FIG. 37.—A Typical Pusher Biplane: The M. Farman of 1914.

FIG. 38.—A Dunne-Type Airplane.

lost control of his machine, perhaps due to fatigue or air-sickness, and was killed in the wreck which followed. Early in 1913, Bielovucci, flying an Hanriot monoplane, duplicated this feat and was more fortunate in his landing. In May of that year Robert Fowler crossed the Isthmus of Panama, following the line of the Panama Canal. A month later Brindejonc des Moulinais flew a Morane-Saulnier monoplane from Paris to Warsaw, stopping for lunch in Berlin. He covered the 933 miles in 11 hours including stops. At the same time in America an over-water cruise was being held on the Great Lakes from Chicago to Detroit, a distance of 880 miles. In spite of storms and other difficulties a Curtiss airplane with boat hull, carrying Verplank and Havens, finished the cruise without mishap, and several other airplanes did excellent work. On September 1, 1913, Pegoud looped-the-loop in a Blériot monoplane, the first time this feat had been done voluntarily. The American continent had already been crossed by Calbraith P. Rodgers, and a prize of $50,000, which had been offered for crossing the Atlantic Ocean, appeared reasonably certain to be won within a year or so. Before the war broke out, an

aviator had flown over Mont Blanc; and Garros had crossed the Mediterranean, feeling so sure of the reliability of the engine in his machine that he did not bother to substitute floats for the wheels of the landing gear.

Repeated mention has been made of airplanes with floats or boat bodies, and it is now time to consider how they developed. Many attempts at flight from the water ended in failure, but in May, 1910, Henri Fabre rose successfully from the Bay of Martigues, near Marseilles. His machine was a double monoplane mounted on three square floats. His success was not marked with this apparatus, but he flew. During the summer of the same year, Glenn H. Curtiss was also experimenting, but without success. Early in 1911, however, Curtiss found the secret of quick and easy planing with a long float, and he soon was selling machines with floats to governments all over the world. The next year he followed up his success by creating the flying boat, an airplane with a boat body. The airplane with floats was quickly copied, but outside of America the airplane with boat body has seldom been built with especial success, except where American designs have been used. Perhaps

the only really successful foreign designs have been the F. B. A., the Macchi, and the Lohner types, of French, Italian, and Austrian manufacture respectively. In this country, this form of airplane developed the first very large machines built. Huge land machines had been constructed abroad, notably by Sikorsky in Russia; but until the *America* was build in 1914, no large machine had been tried in the United States.

The *America* was built to the order of Rodman Wanamaker to win the $50,000 prize for crossing the Atlantic Ocean; but this project, like so many others, was ended or at least indefinitely postponed by the war. In an account of the machine published at the time of her trials (July, 1914) the following description is given: "The principal characteristics and dimensions of the giant Wanamaker-Curtiss trans-Atlantic flying-boat are as follows: Length overall, 34 feet; length of hull, 30 feet; width of hull, 4 feet; depth of hull, 6 feet; length of cabin, 7 feet; height of cabin, 5 feet; width of cabin, 4 feet; spread of upper wing, 74 feet; spread of lower wing, 46 feet; chord, both, 7 feet; gap, between wings, 7½ feet.

"Weight, empty, approximately 3,000

pounds; weight, fully loaded, 5,000 pounds; air-speed, 62-65 miles per hour."

"The power plant consists of two standard model O-X Curtiss aviation motors rated at 90-100 horse-power each. These are mounted midway between the planes, each four and a half feet from the center line. Two propellers, one to each motor, are bolted direct to the motor shafts."

"The fuel supply is contained in a seven-compartment gasoline tank with a total capacity of 312 gallons of gasoline; . . ."

The *America* was afterward improved by the addition of a third 100 horse-power motor. In this form she was sold to the British Government shortly after the war began, and the satisfaction which she gave led to a steady succession of orders for similar and better machines from that time to this.

One of the most striking tendencies in the development of airplanes—in fact by far the most important tendency—has been the rapid and steady increase in the power of the motors. This can be easily illustrated by a comparison of the typical machines at some of the exhibitions and meets. Up to 1911 the motors installed in airplanes were almost without ex-

FIG. 39.—Macchi Flying Boat.

FIG. 40.—Bristol Two-seater Fighting Biplane.
See page 168.

ception small. Even the racers had only 50 to 80 horse-power. By 1911, however, airplane building was firmly established as an industry, and changes were more rapid.

In December, 1911, the Third Paris Aëro Salon was held and twenty-eight makes of airplanes were shown. Twenty monoplanes were exhibited, as against only fourteen biplanes; while of the latter, ten were of the tractor type. The average horse-power of all the machines shown was about 60, the maximum being 100 and the minimum (on a Nieuport which, owing to careful stream-lining, was one of the faster machines in the show) being 28. The leading exhibits were those of Blériot, Deperdussin, and Morane-Saulnier. Typical of the most up-to-date construction of the time was a one-seated monoplane turned out by the last of these firms, and designated as a "racer." The wings of this machine were 29 feet 6 inches in span, and had an area of 118 square feet. The frame of the wings and body was of wood, with steel used in a few places, and the total weight in the air was 1,180 pounds, giving a loading of ten pounds per square foot of wing surface. A seven-cylinder, 50 horse-power Gnome rotary air-cooled

motor, driving a tractor screw, gave the monoplane a speed of 75 miles per hour.

A bit over a year later, in April, 1913, to be exact, the Monaco Meet was held for over-water airplanes. The average horse-power of the machines for which data is available was 117; and while airplanes with either floats or boat bodies were apt to be fitted with bigger engines than land machines, the difference between the 60 horse-power average of December, 1911, and the 117 of April, 1913, can not be explained in that way. The smallest motor was of 80 horse-power, while the largest was a 200 horse-power Salmson Canton-Unné. The lesson learned at this meet was that engine power counts, for the highest-powered airplane, a Bréguet with the 200 horse-power Salmson Canton-Unné, did better than any of the other machines in a race held during a gale. The Bréguet was a two-seated tractor biplane with a single large float.

That this development in engines was not confined to France is shown by the fact that the twenty-one machines entered in the German Prince Henry Circuit, flown that year in May, had an average of 94 horse-power, the lowest being 75 horse-power and the highest 100.

The winner of the tour, Lieutenant von Hiddessen, flew a D. F. W. (Deutsche Flugzeug Werke) monoplane fitted with a 100 horsepower, vertical, six cylinder, water-cooled, Mercédès motor. The monoplane was designed for two passengers, and had a nicely stream-lined body.

The Paris Aëro Salon of December, 1913, did not indicate a marked increase in engine power over the year before. There was an increase (the average was 99) but the chief changes were in the refinements of design. Biplanes and monoplanes were about equal in number, and varied to a large extent in form. The only unusual production which was not a freak was the Morane-Saulnier under-slung monoplane in which the body was hung below the wings, allowing a military observer to have a clear view of everything below him.

The great event which was the real opening of the 1914 season did not take place, however, in France. Early in December, 1913, the Sopwith Aviation Company, an English firm, produced the first small high-speed biplane of a practical type. This little machine, only 25 feet, 6 inches in span by 20 feet in length, attained the surprising speed of 92 miles per hour

[illegible] horse-power Gnome rotary motor; [illegible] still, its low speed was [illegible] miles per hour. When fully loaded [illegible] weighed [illegible] pounds, this [illegible] by main planes with [illegible] square feet. Other British "speed scouts" as they were called, rapidly [illegible] since the Sopwith firm had set [illegible] the most important of these new [illegible] built by A. V. Roe and [illegible] produced by the British [illegible] Company; and the [illegible] of Vickers, Ltd. These machines [illegible] rivals in the world in [illegible] class. The little Sopwith, equipped [illegible] horse-power motor, [illegible] in the race for the [illegible] Cup of Monte Carlo in April, 1914. [illegible] at a speed of [illegible] miles per hour.

[illegible] the situation at the outbreak of the great war. France was undoubtedly the leading nation. The French machines [illegible] — too lightly at times [illegible] being a low weight per [illegible] were splendid flyers. The monoplane was exceedingly popular, much more so,

in fact, than in other countries. In Germany interest in aviation was being actively stimulated by the government through press campaigns and "popular" leagues. The German airplanes were heavily built, and while they could stand rough usage they were sluggish in the air and usually slow. The British had been very slow in developing a native industry; but thanks to the scientific researches of the National Physical Laboratory, the Royal Aircraft Factory was producing a biplane with remarkably fine qualities, and the private firms previously mentioned had no rivals in the building of small biplanes. Italy and Austria, while having native makes of recognized excellence, had produced nothing of international importance. In Russia a real contribution had been made to the world's data on aviation by the experiments of Sikorsky with giant airplanes. These huge machines were destined to become the types from which were developed the great battleplanes of the present. America's only type which was of international importance was the Curtiss airplane with boat body. In all other forms we were usually about a year behind the current European practice of the

period; but Great Britain, France, Germany, Italy and Russia were buying or had bought these American machines.

Such was the situation when the war came. There follows a great gap in the history of aviation. Now and then, through rifts in the smoke of war as it were, we catch glimpses of what is going on over the European battle lines; but the real story must wait, perhaps for years, until the veil of censorship is lifted. We know that "one airplane is worth an army corps." We know, roughly, that for artillery direction and photographic work the old types of biplanes, improved but not radically changed, are still in use. We know that for bombing raids much larger machines are used, and that similar machines are fitted for the work of battleplanes. We know that the wonderful little British biplanes have undergone a transformation at French and German hands (doubtless the British have kept pace with foreign improvements, though we hear nothing of their machines) until today they have become the pursuit machines. And we have a little data, often contradictory, but usually capable of being sifted down to certainties or probabilities.

Except for the German airplanes, data on European two-seated types is scanty. In December, 1916, the Farman, Nieuport, and Spad were reported as building two-seated machines to be equipped with a new 200 horse-power Hispano-Suiza engine. An existing Nieuport equipped with a 150 horse-power Hispano-Suiza had an area of 315 square feet, a useful load of 825 pounds, and a speed of 94.2 miles per hour. A British B. E. (a Royal Aircraft Factory type) had the same motor, a wing surface of 336 square feet, a useful load of 660 pounds, a speed of 96 miles per hour, and a climbing speed of about 860 feet per minute. The German two-seaters of the same period are well represented by the L. V. G.

This machine, driven by a 6 cylinder, vertical water-cooled Mercédès motor, made a speed of 95 miles per hour, could climb about 300 feet per minute, and had a useful load of 980 pounds. The maximum span was 41.3 feet. This machine carried two machine guns and a few bombs. Two more recent Italian airplanes, the S. I. A. and the Pomilio, each carrying a 200 horse-power motor, are reported to have speeds of 118 and 110 miles per hour re-

spectively, and the former can climb over 1,000 feet per minute.

The corresponding American airplanes are probably more ruggedly built, and as a natural consequence they seem to suffer by comparison with the foreign machines. Two well-known types are illustrated in Figs. 41 and 42. The Curtiss R-4 is a powerful machine, driven by a 200 horse-power V-type eight cylinder Curtiss motor. It has a maximum span of 48 feet, 4⅛ inches, an over-all length of 29 feet, a weight of 3,245 pounds, and a supporting surface of 505 square feet. It has a maximum speed of 90 miles per hour, has a climbing speed of 400 feet per minute, and carries enough gasoline to fly for over five and one-half hours. Its useful load is 1,020 pounds, which is greater than those of the foreign machines for which we have data. The Wright-Martin V (Fig. 42) has the advantage of being equipped with the Hispano-Suiza 150 horsepower motor. As a result, its weight when loaded is only 2,310 pounds, requiring a wing area of only 430 square feet. The maximum span, therefore, is less than that of the Curtiss, being only 39 feet, 8½ inches. The maximum speed and rate of climb of this air-

FIG. 41.—Curtiss Model R-2 Military Tractor Biplane.

FIG. 42.—Front Part of a Wright-Martin Model V Biplane.

See page 172.

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plane are not reported, but owing to the use of the Hispano-Suiza motor they probably exceed those of the Curtiss R-4.

The Hispano-Suiza motor, of which frequent mention has been made, is at present reported to be the best in use on the Franco-British battlefront. As can be seen from Fig. 43, it is a V-type engine, very clean in construction. It develops 150 horse-power at 1,450 revolutions per minute, and weighs only 455 pounds (without radiator, water, oil, or exhaust pipes). The two blocks of four cylinders are enclosed neatly; the valves are covered in to keep the dust and oil away from them, and the whole engine can be easily kept clean.

Huge battleplanes are really the exclusive property of the European nations at present. There are American twin-engined airplanes, but none of more than about 250 horse-power except the "seaplanes" with boat bodies. Of the French "avions de chasse" we know little. Handley-Page, an English airplane constructor, has recently produced a huge biplane, (Fig. 44) with a wing-spread of 98 feet and motors totalling about 540 horse-power. It is interesting to notice that the wings have a very clear dihedral angle, presumably to aid in preserv-

ing the stability. The Russian, Sikorsky, built just before the war began a biplane with four 100 horse-power motors, the total weight being three and one-half tons. The Germans have not been asleep while these giants were being produced. Quite early in the struggle they produced a type named "Fritz" by the British. The *London Illustrated News* describes it as follows:

"He is a big brute, anywhere from 80-foot to 100-foot span, and driven by two Mercédès engines of 100 h.p. to 150 h. p. each. These engines are placed in two narrow fuselages, whilst in the centre is a nacelle (body) which contains seats for three men (two gunners and the pilot). The big machine remains aloft on patrol duty for six hours, his engines throttled down to their utmost limit, and thus economizing fuel. Should an enemy appear, the great watcher, some 8,000 feet to 9,000 feet above the Allies' trenches, suddenly accelerates to full speed. From the ground the giant engines can be heard, as they suddenly roar into full power, and the enormous machine can be seen literally to swoop across the sky. With his two machine guns able to fire in any direction, he holds a great advantage over his ene-

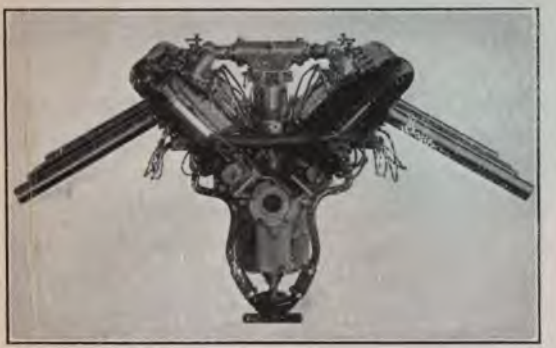

FIG. 43.—The Hispano-Suiza 150 H.P. Aero-Engine.

FIG. 44.—Handley-Page Biplane.
See page 173.

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mies, and when he drives down upon them their only real chance is to dash for home at full speed. The Germans for a model have taken the Italian Caproni machine." In their latest machines, the horse-power has been increased to 520.

The Caproni, copied by the Germans, has now far surpassed the "Fritz." The bombing type, equipped with three 200 horse-power Fiat motors has the remarkable speed of 92 miles per hour, and can climb almost 500 feet per minute. It carries three passengers, three guns, and 2,750 pounds of bombs. A still larger type has 1,800 horse-power, a speed of 80 miles per hour, and fuel for a 12-hour flight; and it can carry five tons of explosives.

The largest American airplane is one with a boat body, the Curtiss H-12. This 400 horse-power air yacht is 92 feet 8½ inches in span, 16 feet 9¼ inches in height, and has main planes with an area of 1,120.78 square feet. Imagine three and a half tons hurtling through the air at eighty-five miles an hour and you will have a good conception of this great airplane at top speed. Some idea of the size may be gained from Fig. 45. These great machines, probably far superior to any others

of their type in the world, are now being built for the United States Navy, and will probably also be supplied to the British government which has found similar machines useful throughout the war.

The most interesting of all the types in use is the fast fighter, the little pursuit machine.

These little airplanes are the fastest things in the air. Carrying one man and a machine gun which is fixed to fire straight ahead through the propeller, they dash upon an enemy with a speed of more than 125 miles an hour. The Italians assert that they have the fastest airplane in the world, the S. V. single-seater fighting tractor, which they say can fly 139 miles per hour and climb 1,250 feet per minute. This report is not unreasonable in its assertions, although the greatest speed for a pursuit airplane of which we have authentic data is 125 miles per hour. The frequent press reports of airplanes flying 160 to 170 miles per hour may safely be considered the bragging of irresponsible partisans. The only other plausible explanation of these statements is that when, let us say, 170 is mentioned as the speed of an airplane, 170 *kilometers* per hour (102 miles per hour) is meant.

Fig. 45.—A Curtiss Twin-Engined Flying Boat.

Fig. 46.—A Nieuport Pursuit Machine.
See page 177.

FIG. 47.—A Spad Biplane.

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No information is available as to the British pursuit machines. A little, however, is known of French airplanes of fairly recent date. The Nieuport, shown in Fig. 46, has a span of 24 feet 6 inches on the top plane and of 23 feet on the bottom plane. It is, as can be seen, a single seater, and it is equipped with an 80 horse-power rotary air-cooled Le Rhône engine. Its endurance is 2½ to 3 hours, and it climbs from 600 to 700 feet per minute; but unfortunately the maximum speed is not known authentically. The Spad (S.P.A.D.), developed since the war began, has become one of the leading French pursuit machines. One type was fitted with a 150 horse-power Hispano-Suiza motor and did 125 miles an hour. Its wing area was 185 square feet, the useful load 460 pounds, and it could climb 920 feet per minute. A Blériot of the same period had, it may be mentioned, identical characteristics. The Spad illustrated in Fig. 47 is said to be a more recent type. This machine, the S. VII model, is reported to be 25 feet 6 inches in span, 20 feet in length, and carries one man and one or two machine guns. Its total weight is 1,525 pounds, its useful load 470 pounds, and it can climb 930 feet per minute. Its eight cylinder, 160 horse-power His-

pano-Suiza motor drives it through the air at 132 miles per hour speed, we are told. The picture of the Morane monoplane which was given earlier (Fig. 29) indicates that the biplane and triplane do not have a monopoly of the fast fighting machines. No details beyond those shown in the photograph, however, are known.

The German tendency to heaviness of construction, which was strong before the war, still persists in the motors, but has vanished elsewhere. Fig. 48 shows the Albatros destroyer, known as Type D. 1. A machine of this pattern was shot down on the British front about December 1, 1916. It was 28 feet in wing spread, 24 feet overall in length, and had main planes with an area of 263 square feet. It was driven by a 170 horse-power Mercédès motor. Of the more recent German types we have no data, but they have changed in only minor details from the D. 1 type.

The United States has produced one excellent pursuit machine for which data is available. By this time there doubtless are more, but no information has been published about them if they exist. The Curtiss Company has brought out a triplane (Fig. 49) which attains

Fig. 48.— A Curtiss Pursuit Triplane.

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the very creditable speed of 120 miles per hour with a 100 horse-power motor; and the factor of safety has not been reduced as in the European airplanes. The wing spread of this machine is 25 feet; the length overall, 18 feet; the chord of the wings, 2 feet; and the gross weight, 1,060 pounds. The climbing speed is reported to be 1,000 feet per minute. The minimum speed is only 56 miles per hour. This minimum speed is important, for airplanes must run along the ground in starting until they attain it, and must slow down from it in alighting. Some of the foreign machines are said to land at from 70 to 80 miles or more, and as a result they can only start from and return to special fields of large size and absolutely perfect smoothness. These fields constitute a real limitation to the usefulness of fast machines, as they are necessarily few.

In conclusion it may be remarked that American airplanes are often said to be inferior to European machines. Not long ago this was true, but for about a year it has not been true. American machines were not designed for the same purpose as the foreign fighting machines, and this fact has led to misunderstandings. The American training machines and the Cur-

fine airplanes with boat bodies have proved equal and superior to the best of their foreign competitors, and these types have been the only ones for which American builders have received war orders. Now that the United States Government has asked for military airplanes, they will be forthcoming, for American constructors are fully able to meet the new demands with success.

# CHAPTER VI

## THE FUTURE OF AËRIAL NAVIGATION

WITH the accomplishment of human flight by machines heavier than air, and the improvement of the dirigible balloon, it is natural that speculation should be rife concerning the influence which aërial navigation may have on mundane affairs.

Although the facility of traversing the atmosphere more or less freely in three dimensions is now afforded, this is less startling than was the opening of the vast depth of the atmosphere to exploration by the invention of the balloon 134 years ago. At that time public interest in France was greatly excited by the wonderful extension of the realm of man, and the famous Lavoisier was asked by the Academy of Sciences to draw up a report on the value of the new discovery, but it is related that the great chemist was unable to enumerate the multitude of problems which the balloon could solve. As we now know, however, the free

balloon has been of little use except as a means of exploring the atmosphere.

We can easily understand that with the acquisition of this new field of locomotion which dominated land and water the direction of the balloon seemed easy and its uses many, and they were thus described by an unknown French author in 1783: "For peaceful purposes there may be specified:— Making maps, signaling at great distances, communicating with distant countries, making astronomical observations above the smoke and haze and with a wider horizon, etc. For comfort and pleasure there never was a more prolific invention than the balloon. No one will go on foot when a carriage can be had so cheaply. The air will furnish an easy route which does not need repairs and is never crowded. Finally the destructive agencies of the balloon are numerous, as is unfortunately the case with most of the great discoveries. Balloons will serve to cross rivers, to erect ambuscades, to surprise places, and to crush entire armies on the march, for a balloon 100 feet in diameter can sustain at a great height in the air a weight of several thousand pounds, and therefore can carry at least 10 soldiers with fire-grenades, and other

modern missiles, which may be rained down upon the troops. Moreover, 200 balloons of this size could, in a few minutes, disembark in a besieged place 2,000 grenadiers with their arms, and ten minutes later might bring over a similar force. The cost is certainly less than that of batteries, and the fate of such places as Gibraltar would be certain."

Fanciful as these ideas were at that time, the assertions of the wonders which aërial navigation is going to work are even more bold today, and in this concluding chapter the possibilities of airships and flying machines will be considered in the light of expert and conservative opinion.

The predictions of the French writer at the end of the eighteenth century, concerning the balloon as an agent in warfare, have been fulfilled neither by the free balloons with which he was familiar, nor by the dirigibles which succeeded them. Scouting is actually the chief rôle of the present military dirigible, and it appears to best advantage when attached to a fleet. A dirigible balloon, moving faster than the fastest torpedo boat, can extend its investigation over a large radius and report (by wireless telegraph or telephone) to flagship or naval

base the presence and strength of the enemy's ships while they are still far distant. Moreover, since high above the surface of the sea its depths can be plainly discerned, the dirigible is in a position to discover a submarine or a mine which would be invisible from the surface itself, even were it quite smooth; and by virtue of this ability it is invaluable as a convoy. In the balloon, the carrying capacity is proportional to the volume, which increases as the cube of the surface and weight, and these increase only as the square of linear dimensions; and thus there is an advantage in large size. The dirigible, however, has probably nearly reached the limits of its development, and although its size and speed may be increased with advantage, it will not come into general use on account of the cost of construction, operation, and maintenance, which will cause it to be supplanted by the airplane wherever possible. Moreover, just as sea-captains must use care in entering a port during a storm, so aëronauts must be very cautious about approaching the earth when the wind is high. So long as the dirigible remains in the air it may be regarded as tolerably safe, for even if its engines are disabled it can still serve as a free

balloon; but when brought in contact with the ground, if it is disabled by engine failure, it is in great danger of being wrecked on account of its fragile structure and its momentum, especially if the balloon is large. For these reasons it seems probable that the dirigible balloon will eventually give place to the airplane wherever aircraft are of use.

A quadruped on the ground, a fish floating in the water, or a balloon in the air are sustained without any work being done, but it must be remembered that the flying machine, being heavier than air, must expend force to maintain both lift and speed. The measure of this work is that required to impart to the apparatus a definite speed, and this velocity is the greater as the weight per unit area of sustaining surface is the larger. It can be shown that flight by downward strokes is impossible unless the weight per horse-power is less than two pounds. As this is not yet possible, we must give the surface what Colonel Renard called "sustaining quality," of which the fundamental principle consists in attacking the air obliquely instead of vertically. Since the helicopter is not yet practical, the velocity necessary to provide the "sustaining quality" must

be gained by a flying start; and for this reason airplanes have the inconvenience of requiring a large space for starting and landing which is also true of large birds like the condor.

In the process of perfecting the airplane we may look forward confidently to the development of higher efficiency and lighter and more reliable motors. Not less confidently may we expect to see vastly larger machines and far wider ranges of speed. Farther in the future we may hope for the solution of the problem suggested above — that of starting from and alighting in a confined space. It is possible that the answer may lie in lighter motors combined with a union of the airplane and the helicopter, whereby the machine would rise as a helicopter and then fly as an airplane. Such a "helicoplane" would also solve the problem of slowing up and stopping in the air. Still more distant, but not without the range of possibility, is the wireless transmission of power, which will make airplanes independent of fuel supply and therefore limitless in radius of action.

Airplanes are already indispensable in war, for they eliminate the element of surprise, and are valuable offensive weapons. How much more vital they will eventually become, no one

can prophesy, but it is not outside the bounds of imagination that wars of the future may be not only decided but wholly fought in the air. In the realm of sport and pleasure, airplanes promise to be used much in the same way as automobiles, since they possess the advantage over present vehicles of being absolutely independent of the nature of the ground over which they travel. Therefore, they can go in a straight line, regardless of the topography of the country, surmount hills or mountain ranges, and cross bodies of water, while taking the shortest route between the points of departure and destination. Until means are devised for starting and landing in restricted areas this cannot be done within cities, or in mountainous or wooded regions; but, as regards the cities, municipal landing fields will eventually be provided.

Evidently aërial transit may facilitate lawbreaking in certain ways. For instance, it will be difficult to maintain a customs service on frontiers which can be traversed at a great height and by night, and perhaps this freedom of the air will bring about free trade among the nations. The law of trespass must be amended to limit the extent of ownership above real

estate. But on the whole we can agree with Mr. Chanute that dirigible balloons and flying machines are not likely to upset materially existing conditions of life, as is frequently predicted. Their design and performance will doubtless be improved from time to time, and they will probably develop new uses of their own which have not yet been thought of, but that is all.

At the International Congress of Aëronautics, held in connection with the Paris Exposition of 1900, the delegates of the United States government were Professor Langley and the author. The president of the Congress, Dr. Janssen, director of the Astrophysical Observatory at Meudon, like Professor Langley, was a firm believer in the speedy accomplishment of aërial locomotion, but unfortunately both these distinguished physicists died before they had seen men perform mechanical flight. In the light of subsequent progress, the prophetic vision of the age of aërial navigation, which Dr. Janssen described in his address to the Congress in the following sentences, to-day appears like the handwriting on the wall to disturb the peace of mind of Great Britain, secure hitherto in her insularity:

"Themistocles said: 'He who shall make himself master of the sea is destined to become master of the land.' Now if the ocean has given this power to the nation that was wise enough to seize it, how much greater will be the coming mistress of the air? While the sea separates and renders passage of even a narrow channel difficult in the face of a hostile force, the air unites all nations and offers a route from any point on the earth's surface to any other, which can be traversed with impunity, no matter how vigilant the patrol. Political or natural frontiers will no longer form barriers between states when aërial fleets can sail over them."

The advent of aërial navigation does not find Dr. Janssen's hope realized that the conquest of the air might come when civilization has reached such a high plane that it will recognize justice, right, and peace as alone consistent with the welfare of mankind. Its first use, indeed, has been for war. But, while it may not lead to Utopia, the entry of man into a domain to which Nature seemed to have denied him access forever, will certainly constitute, by virtue of the constancy and intensity of the efforts that it has cost, and by the dis-

conveniences and necessities which it will have provided, one of the highest titles to glory of which the human race is able to boast.

FINIS

GEORGES GUYNEMER
"The Winged Sword of France"

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## GEORGES GUYNEMER

*It seems only proper and fitting to close this little work on the "CONQUEST OF THE AIR" with a just tribute to the most distinguished conqueror, the late Georges Guynemer, who was called "The Winged Sword of France." The following account and appreciation of the immortal French ace has been prepared by Ladislas d'Orcy.*

Captain Georges Guynemer was regarded as the most brilliant aviator not only of the French Flying Corps, but of the war. Only twenty-one years old, he achieved some of the greatest aerial feats of the conflict, and won with fifty-three victories officially to his credit nearly every military honor which his country could bestow in the two years he fought for France.

Guynemer joined the French Aviation Corps in 1915, after brief service as a private. In Feb., 1916, he brought down his fifth machine, and became an "ace." Other and greater victories followed in rapid succession.

In 1916 the Academy of Sports awarded

the young aviator a 10,000-franc prize for "the best sporting event of the year." At the end of the same year, with his Captain's stripes, he received the Cross of the Legion of Honor.

His greatest day's work was on May 17, 1917, when he brought down four German machines, two of which he accounted for in the space of two minutes, having attacked a group of four. With only three cartridges left, while on his homeward flight he encountered the fourth German and shot him down with one of the three remaining cartridges.

Captain Guynemer was frequently asked by Daniel Vincent, when the latter was Under-Secretary of Aviation, to come to the rear and place his talents as an inventor and his vast experience in war flying at the disposal of the air administration. Guynemer, however, invariably refused, being unable to bring himself to give up the fascinating, adventurous life of an air fighter.

Captain Guynemer is thought to have been killed during a reconnoissance flight over Flanders, on which he left Dunkirk on Sept. 11. Nothing has been heard of him since.

What was probably his last combat is described by a comrade as follows:

"Guynemer sighted five machines of the Albatros type D-3. Without hesitating, he bore down on them. At that moment enemy patrolling machines, soaring at a great height, appeared suddenly and fell upon Guynemer.

"There were forty enemy machines in the air at the time, including Count von Richtofen and his circus division of machines, painted in diagonal blue and white stripes. Toward Guynemer's right some Belgian machines hove in sight, but it was too late.

"Guynemer must have been hit. His machine dropped gently toward the earth, and I lost track of it. All that I can say is that the machine was not on fire."

Additional details of Guynemer's death were furnished by Major Brocard, commander of the "Storks," the squadron to which Guynemer belonged, in the Paris *Le Matin.*

According to him the last fight of the great French aviator occurred four or five miles inside the German lines northeast of Ypres and opposite the British lines. Captain Guynemer was accompanied by Lieutenant Bozon Verduraz, who says that they were flying at a height of 15,000 feet when Guynemer sighted an enemy two-seater, which he attacked.

Almost at the same moment Verduraz saw four German monoplanes approaching and turned toward them instantly so as to draw them off. They circled around for a while and then disappeared. Verduraz then returned to the place where he had left Guynemer engaged with the German biplane, but Guynemer had vanished.

Information gathered from neutral sources tends to show that Guynemer was shot through the head, north of Poelcapelle, on the Ypres front. His body was identified by a photograph on his pilot's license found in his pocket. The burial took place at Brussels in the presence of a guard of honor, composed of the 5th Prussian Division.

The burial was about to take place at Poelcapelle, when the bombardment preceding the British attack at Ypres started. The burying party hastily withdrew, taking the body with them. The German General chanced to be an aviation enthusiast with a great admiration for Captain Guynemer's achievements.

At his direction the body was taken to Brussels in a special funeral car. Thither the captain was carried by non-commissioned officers and was covered with floral tributes from Ger-

mate aviators. The Prussian Guards stood at salute upon its arrival and during the burial, which was given all possible military honors.

Such was the end of Captain Guynemer, France's great air fighter. A tablet bearing his name was subsequently placed by the French government in the Pantheon, where many great Frenchmen are buried, to perpetuate the memory of Captain Guynemer as "a symbol of the aspirations and enthusiasm of the Army."

The victor of Captain Guynemer did not, however, enjoy his laurels for a long time. It soon became known in the French Flying Corps that the man who vanquished Guynemer was Lieutenant Wisseman, of the German Pursuit Flyers, and the comrades of Guynemer at once decided to avenge the French ace's death. A fortnight later Lieutenant Fonck, of the French Flying Corps, succeeded in engaging Wisseman and brought him down in flames. This combat was described as follows:

"Fonck was executing an air cruise at a height of 19,000 feet. Suddenly spying a 'Rumpler' of the new model, he precipitously made to meet it. The boche, without apparent ceremony, opened fire. This, however, was without success. Fonck, operating and ma-

neuvering by turns and glides, approached him 'en titubant' (a motion as if staggering), thus preventing the enemy 'mitrailleur' from forcing him into his line of aim. When Fonck found himself in a favorable position, somewhat under and back of the enemy machine, he fired a burst of ten shots. Wissemann was instantly killed.

"The observer was thrown out of the cockpit and dropped through the air a distance of 18,500 feet, passing, on his voyage to earth, within less than ninety feet of Fonck like a rapidly descending stone. The Rumpler turned herself over and came down with folded wings in a vertical line and struck on her back. It was the most frightful of falls, and Guynemer was well avenged.

"Fonck landed near his victims and hurried to the mass of debris under which was buried the dead boche, who had died with a bullet in the head, and who, judging from his new decorations, had been promoted to the rank of captain as a reward for having killed Guynemer."

This notable air feat on the part of Fonck was accomplished on the 30th of September. The avenger of Guynemer has brought down in battle with the enemy fifteen avions, five of

them having been shot down in six days' time. As proof of his wonderful ability in the execution of aerial warfare, he has never fired more than ten shots in landing an enemy machine, nor has he ever brought back with him the traces of battle, not one ball ever having grazed his war plane. His breast glitters with the French "medaille militaire," the "croix de guerre," with eight palms (and two more coming), the military cross and the English military medal, Fonck being the only Frenchman possessing these two rewards for bravery, the cross of the chevalier of the Order of the Belgian Crown and the Belgian war cross.

Guynemer's last night in Paris was the 8th of September, just three days before he was [illegible] friend who saw him that day wrote [illegible]

[illegible] Paris hotel elevator, accompanied by his [illegible] He was ill, pale and [illegible] yet his sparkling black [illegible] with ambition and beamed [illegible] as his vision fell upon a [illegible] passed from the elevator into [illegible] of him. She had been [illegible] whisper [illegible] He must go in front; we

must not drag him along behind us like an ordinary mortal.'

"We were attracted to him by the red rosette that stood out from his child-like breast, for he was as slim and as willowy as a maiden of his own age. Along by the side of this emblem of glory, resting on a war cross ribbon horizontally placed about his body, were tiny palms, too numerous to count.

"This same beautiful girl, in lowest of tones, had murmured, 'Guynemer.' In her voice was that tone which reveals deeply felt sentiment possessed and nourished only by the real and true woman, and which expresses at once both tenderness and admiration.

"Guynemer! Hardly had the name been pronounced when all conversation suddenly ceased, even the 'garçon' forgetting the proper manipulation of his 'guidon' and his 'ascenseur' stopped midway between two floors.

"While thus detained we listened:

"The Doctor — I assure you that you need rest; you should be persuaded to take it.

"Guynemer (in precise tones) — Useless. I should refuse.

"How young! What determination in his

voice! Why did he not follow the advice of the physician?

"Who knows? Perhaps in his ear was whispered by the inaudible voice of an invisible angel, 'Such a man should not die in his bed.'"